

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
2 August 2001 (02.08.2001)

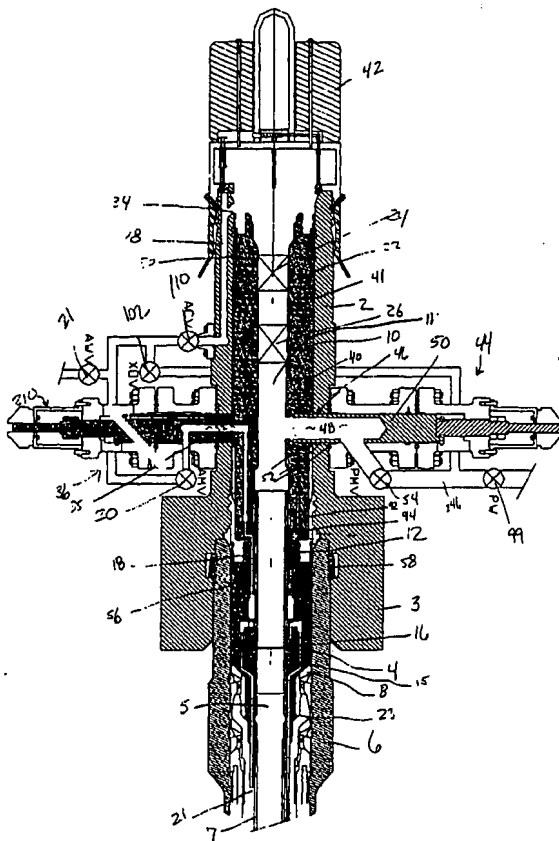
(10) International Publication Number
WO 01/55550 A1

PCT

- (51) **International Patent Classification⁷:** E21B 33/04 (74) **Agent:** WHITE, Carter, J.; Howrey Simon Arnold and White, LLP, 750 Bering Drive, Houston, TX 77057-2198 (US).
- (21) **International Application Number:** PCT/US01/02938
- (22) **International Filing Date:** 29 January 2001 (29.01.2001)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
- (30) **Priority Data:**
60/178,845 27 January 2000 (27.01.2000) US
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- (81) **Designated States (national):** AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW.
- (84) **Designated States (regional):** ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

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(54) Title: CROSSOVER TREE SYSTEM



(57) Abstract: A subterranean oil or gas well apparatus is provided. The apparatus includes a single-bore production tubing hanger (4) arranged concentric with a wellhead (6). The tubing hanger includes a plurality of ports (17, 19) and channels arranged about the tubing hanger to give operators access to the production tubing annulus and provide chemical injection capability. The ports are closed by a sliding valve (16). The apparatus also includes annulus and production radial-bore stab assemblies (12) between a christmas tree (2) and an internal crossover assembly (10). The stab assemblies are extendable and retractable between the christmas tree and the crossover assembly to allow the retrieval and installation of each independently.

WO 01/55550 A1

WO 01/55550 A1



Published:

— with international search report

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

CROSSOVER TREE SYSTEM

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This application claims priority of U.S. Provisional Application No. 60/178,845, filed January 27, 2000, the specification of which is hereby incorporated by reference.

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FIELD OF THE INVENTION

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This invention relates generally to subsea oil and gas production methods and apparatus and, more particularly, to a crossover christmas tree system.

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BACKGROUND OF THE INVENTION

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It is conventional practice to complete a subsea well with a multi bore tubing hanger with tubing suspended below. One bore is a production bore of between 5 and 10 inches nominal diameter and the other is a smaller annulus bore of about 2 inches. The tubing hanger and the associated tubing are run into a subsea wellhead on a running assembly comprising a tubing hanger running tool and a multi bore riser until the tubing hanger is landed and sealed in a wellhead housing. The wellhead carries a blowout preventor (BOP) stack which is connected to a marine riser through which the tubing hanger is run.

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This configuration, with the bores side-by-side is typical because it is relatively simple to seal off the bores in the tubing hanger. This is done immediately after the tubing hanger has been landed by running and setting at least one plug into each bore through the multi bore riser used to install the tubing hanger using a wireline technique so that the plugs close the bores and secure the well during the time the tubing hanger is exposed to the ambient environment.

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1 Once the plugs are installed, the multi bore riser is disconnected from the tubing
2 hanger and retrieved to the surface, after which the BOP stack is disconnected from the
3 subsea wellhead and retrieved to the surface with the marine riser. At this point, the
4 tubing hanger is exposed to the ambient environment. The multi bore riser is re-used to
5 run a Christmas tree which is landed and locked into the subsea wellhead simultaneously
6 establishing connections to the tubing hanger. The Christmas tree is installed using a
7 running assembly comprising the multi bore riser, a safety package including wireline
8 cutting valves and an emergency disconnect package which allows the separation of the
9 surface vessel in the event that it becomes necessary to disconnect the surface vessel from
10 the wellhead. The multi bore riser leads from the upper end of the emergency disconnect
11 package to the vessel. Wirelines can be deployed through the multi bore riser, the safety
12 package and the Christmas tree in order to retrieve the plugs in the production bore and
13 the annulus bore. The Christmas tree valves are then shut while the safety package and
14 the multi bore riser are retrieved to the surface. The Christmas tree is then capped.

15 In deeper water, the viability of such a conventional multi bore riser is open to
16 question both from structural and commercial viewpoints. In addition, there are many
17 applications in which a larger full bore is desirable. Alternatives to multi bore riser
18 systems utilizing a single bore have been proposed for running and for operating with a
19 christmas tree but, while they can be used for plugging the production bore, they suffer
20 from the problem of providing annulus access with sufficient flow rate capacities to treat
21 a well--and the lack of annulus flow control.

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1 Further, in deep water it becomes very difficult to align side-valve christmas tree
2 ports with the tubing hanger.

3 Finally, well drilling and completion operations are very expensive and often
4 based on per hour rig charges. It is desirable to complete wells with a few downhole trips
5 as possible to reduce rig time. In a conventional tubing hanger and christmas tree
6 assembly, the retrieval of the tubing hanger also requires the retrieval of the christmas
7 tree. It would be desirable and cost efficient to find a system that would allow separate
8 retrieval of the christmas tree and tubing hanger.

9 The present invention is directed to eliminating, or at least reducing the effect of,
10 one or more of the issues raised above.

11 SUMMARY OF THE INVENTION

12 The invention is directed to a style of Christmas tree wherein the tubing hanger is
13 landed in the wellhead, and both the tree and the tubing hanger can be removed
14 independently. This independent ability to retrieve either the tree or the tubing hanger, as
15 required, is achieved through the use of a crossover piece in the tree. When installed, the
16 crossover piece directs the flow of the production fluid to the production valves outside
17 the tree, and directs the flow of fluids to or from the tubing annulus. When the crossover
18 piece is removed, full-bore access through the tree is available, and the tubing hanger,
19 landed below the tree can be removed with the tree in place. One exemplary embodiment
20 of the present invention encompasses a subterranean oil or gas well assembly. Such an
21 embodiment includes: a wellhead; a christmas tree coupled to the wellhead; and a tubing
22 hanger landed within the wellhead. A sliding valve is disposed within the tubing hanger

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1 to selectively allow fluid communication between a first port in the sliding valve and a
2 first port in the tubing hanger. A crossover assembly is landed within the tree body, and
3 a crossover stab is disposed within the crossover assembly and adapted to translate the
4 sliding valve between open and closed positions.

5 A subterranean oil or gas well assembly comprising: a wellhead; a christmas tree
6 coupled to the wellhead; and a single bore tubing hanger landed within the wellhead. The
7 tubing hanger includes production tubing suspended from it as should be known in the
8 art. The single bore tubing hanger further includes a plurality of first closable ports
9 which facilitate fluid communication to an annulus defined by the production tubing and
10 an innermost casing.

11 These and other features of the present invention are more fully set forth in the
12 following description of preferred or illustrative embodiments of the invention.

13 BRIEF DESCRIPTION OF THE DRAWINGS

14 The foregoing and other features and aspects of the invention will become further
15 apparent upon reading the following detailed description and upon reference to the
16 drawings in which

17 Figure 1 depicts a crossover tree design in accordance with one aspect of the
18 invention.

19 Figure 2 depicts the installation/retrieval of the tubing hanger.

20 Figure 3 depicts the installation/retrieval of the tubing hanger.

21 Figure 4 depicts the tubing hanger in the wellhead and temporarily abandoned.

22 Figure 5 depicts running the tree with the tree fully assembled.

23 Figure 6 depicts a preparation position for retrieving the tree cap and crossover
24 assembly.

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1 Figure 7 depicts the installation/retrieval of the crossover assembly.

2 Figure 8 depicts full bore access through the tree.

3 Figure 9a - 9c depict a view of the alignment mechanism on the crossover
4 assembly.

5 Figure 10 depicts a hydraulic schematic for the crossover tree system (CTS) in the
6 production mode.

7 Figure 11 depicts a perspective overview of the CTS.

8 Figure 12 depicts a cross sectional view of the CTS in the initial sequence
9 positions.

10 Figure 13 depicts a cross sectional view of the CTS in the retrieve BOP
11 stack/ROV install debris cap sequence.

12 Figure 14 depicts a cross sectional view of the CTS in the tree running sequence.

13 Figure 15a depicts a cross sectional view of the CTS in the extend the crossover
14 assembly stab into the tubing hanger sequence.

15 Figure 15b depicts a cross sectional view of the CTS in the extend the crossover
16 assembly stab into the tubing hanger sequence, in a second position.

17 Figure 16 depicts a cross sectional view of the CTS in the retrieve tubing hanger
18 wireline plug/install crossover wireline plug/retrieve tree running tool/ROV install debris
19 cap sequences.

20 Figure 17 depicts a cross sectional view of the CTS in the optional sequence of
21 locking the empty spool body onto the wellhead with the tree running tool.

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1 Figure 18 depicts a cross sectional view of the CTS in the optional sequences of
2 locking the BOP stack onto the spool body, running the tubing hanger with a multi-
3 purpose running tool, and installing the tubing hanger wireline plug.

4 Figure 19a depicts a cross sectional view of the CTS in the optional sequence of
5 running the crossover assembly with the multi-purpose running tool in a first position.

6 Figure 19b depicts a cross sectional view of the CTS in the optional sequence of
7 extending the crossover assembly stab into the tubing hanger in a second position.

8 Figure 20a depicts a cross sectional view of the CTS in the optional sequence of
9 extending the crossover assembly stab into the tubing hanger in a first position.

10 Figure 20b depicts a cross sectional view of the CTS in the optional sequence of
11 extending the crossover assembly stab into the tubing hanger in a second position.

12 Figure 21 a cross sectional view of the CTS in the optional sequences of
13 retrieving the tubing hanger plug, installing crossover plugs, retrieving the BOP stack,
14 and ROV installing the debris cap.

15 Figure 22 depicts a combination detail of the side stabs.

16 Figure 23 depicts the tubing hanger shuttle valve detail.

17 Figure 24 depicts the tubing hanger shuttle valve detail in cross section.

18 Figures 25a - 25c depict details of the annulus flow paths.

19 Figure 26 depicts a cross-sectional top view of the CTS.

20 Figure 27 depicts a top view of the CTS and retractable stab mechanism.

21 Figure 28 depicts a detail of the bevel gears of the retractable stab mechanism.

22 Figure 29 depicts a perspective view of the apparatus according to Figure 27.

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1 Figure 30 is an alternative embodiment of the christmas tree.

2 Figure 31 depicts a cross sectional view of the CTS with a safety tree.

3 Figure 32 depicts a cross sectional view of the CTS in the crossover assembly
4 installation sequence.

5 Figure 33 depicts a cross sectional view of the installation/retrieval of the tree.

6 Figures 34 - 35 depict a detail of the crossover assembly/hanger interface.

7 Figure 36 depicts a perspective view of the annulus stab mechanism.

8 Figures 37 - 38 depict details of the electrical interface between the crossover
9 assembly and the tubing hanger.

10 Figure 39 depicts a multiple use running tool.

11 While the invention is susceptible to various modifications and alternative forms,
12 specific embodiments thereof have been shown by way of example in the drawings and
13 are herein described in detail. It should be understood, however, that the description
14 herein of specific embodiments is not intended to limit the invention to the particular
15 forms disclosed, but on the contrary, the intention is to cover all modifications,
16 equivalents, and alternatives falling within the spirit and scope of the invention as defined
17 by the appended claims.

18 **DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS**

19 Illustrative embodiments of the invention are described below. In the interest of
20 clarity, not all features of an actual implementation are described in this specification. It
21 will of course be appreciated that in the development of any such actual embodiment,
22 numerous implementation-specific decisions must be made to achieve the developers'

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1 specific goals, such as compliance with system-related and business-related constraints,
2 that will vary from one implementation to another. Moreover, it will be appreciated that
3 such a development effort might be complex and time-consuming, but would
4 nevertheless be a routine undertaking for those of ordinary skill in the art having the
5 benefit of this disclosure.

6 Previous attempts to develop a tree with the advantages of a crossover tree have
7 resulted in designs wherein a false or dummy tubing hanger is installed in the tree.
8 United States Patent No. 5,372,199 is one example of such a design. Similar designs
9 were offered for sale by National Oilwell prior to the date of the cited patent. However,
10 such designs were cumbersome and required additional steps to retrieve specific
11 components. The current invention overcomes this and other limitations of the prior art
12 trees.

13 Turning now to the Figures, and in particular Figure 1, a Crossover Christmas tree
14 2 with a tubing hanger 4 installed within a wellhead 6 in accordance with one
15 embodiment of the invention is disclosed. The assembly shown in Figure 1 represents
16 one embodiment of the crossover tree system and the associated assembly fully installed.
17 Tree 2 is connected to a wellhead 6 by a tree connector 3. As shown in Figure 10, tree
18 connector 3 can be hydraulically actuated such that a lock down ring 58 mates with an
19 exterior profile on wellhead 6. Other types of tree connectors generally known in the art
20 can be adapted to couple the tree 2 to the wellhead 6.

21 The assembly shown in Figure 1 includes tubing hanger 4, which is installed
22 substantially concentrically within wellhead 6. In one embodiment, tubing hanger 4 is a

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1 concentric tubing hanger, seven inches in diameter, but may range in size as required for
2 a particular field development. Eccentric or dual bore tubing hangers may be used, in
3 other embodiments not shown. Tubing hanger 4 rests on a shoulder 8 of wellhead 6, and
4 the annulus between then tubing hanger 4 and the wellhead 6 is sealed. A tubing hanger
5 lock down ring 56 helps secure tubing hanger 4 within tree 2. The lower end of tubing
6 hanger 4 suspends a downhole tubing 7 (shown schematically in Figure 10) to facilitate a
7 production flow from wellbore to surface when the downhole safety valve 9 is open.

8 A crossover assembly 10 is disposed within the bore of the crossover tree 2 such
9 that the assembly bore 11 is substantially coaxial with the bore 5 in the tubing hanger 4.
10 A crossover stab 12 sealably mates with tubing hanger 4. The annulus between the
11 crossover assembly 10 and the tree 2 is sealed, for example by crossover seal 40 disposed
12 between the crossover assembly 10 and tree 2.

13 In the embodiment shown in Figure 1, crossover assembly 10 and crossover stab
14 12 are installed substantially concentrically with hanger 4, with the distal end of
15 crossover stab 12 extending partially through the interior of hanger 4. As seen more
16 distinctly in Figures 15A and 15B, a plurality of seals 14 seal between hanger 4 and
17 crossover stab 12. Disposed between crossover stab 12 and hanger 4 is a sliding valve
18 16, which may also be called a shuttle valve. Sliding valve 16 is shown in the down or
19 operating position in Figure 1 (the details of sliding valve 16 are discussed below). In
20 some embodiments a biasing element, such as a compressed spring, may be disposed in
21 the area labeled 15 in the Figure 1 embodiment to bias the sliding valve 16 to a closed
22 (up) position wherein ports such as 17 and 17a (as shown more clearly in Figures 15A

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1 and 15B) are misaligned. In the embodiment shown sliding valve 16 is actuated between
2 open and closed position by the application of hydraulic pressure to space 15.

3 Referring to Figures 23 and 24, sliding valve 16 may include a body 156 with
4 opposing ports or bores 17 and 19. In the embodiment of Figure 1, bore 17 is an annulus
5 access bore or port. Bore or port 19 is shown in the embodiment of Figures 23 and 24 as
6 a chemical injection bore. Body 156 of valve 16 may exhibit flat machined faces 152 and
7 154 on the outer diameter of the body at bores 17 and 19. A second annulus port 17a
8 with a sealing face meets flat machined face 152. Port 17a is attached to a spacer 164
9 and is in fluid communication with annulus access bore 18 via a plurality of holes 166
10 arranged about the circumference of the spacer. A plurality of seals (not shown) seal
11 between spacer 164 and second port 17a.

12 Adjacent to spacer 164 opposite the port 17a is an adjustable plug 168. A
13 plurality of seals (not shown) on adjustable plug 168 inhibits leakage past the plug.
14 Adjustable plug 168, spacer 164, and port 17a are arranged within a radial bore 170 in
15 tree 2. Adjustable plug 168 may have a hex recess 172 to allow an operator to adjust the
16 compression between machined face 152 on and the sealing face of port 17a.

17 As shown in the figures, valve 16 may include a chemical injection bore or port
18 19. Chemical injection port 19 includes a chemical injection adjustable plug 174 adjacent
19 a chemical injection spacer 176. Chemical injection spacer 176 includes a plurality of
20 holes 178 to facilitate fluid communication with a chemical injection bore 23 in tubing
21 hanger 4. Chemical injection adjustable plug 174 may include a plurality of seals (not
22 shown) to inhibit leakage past the plug. Chemical injection spacer 176 attaches to

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1 chemical injection second port 19a. Chemical injection second port 19a includes a
2 sealing face which meets flat machined surface 154. Chemical injection adjustable plug
3 174, spacer 176, and second port 19a are arranged within a second radial bore 178 in tree
4 2. Chemical injection adjustable plug 174 may have a hex recess (not shown) to allow an
5 operator to adjust the compression between machined face 154 on and the sealing face of
6 second port 162.

7 As shown in Figure 23, shuttle valve 16 is in a first or closed position. A first
8 plurality of seals 180 inhibit fluid leakage between body 156 and hanger 4. A second
9 plurality of seals 182 may further inhibit fluid leakage. The seals may include a primary
10 metal-to-metal seal and secondary elasomer or polymer seal, with retainers in between.
11 In the first position (shown in Figures 23 and 24), annulus access bore 17 is not aligned
12 with second annulus access port 17a. Likewise, chemical injection bore 19 is not aligned
13 with second chemical injection port 19a. However, in some embodiments, one or both of
14 annulus access bore 17 and chemical injection bore 19 is in fact lined up with its
15 associated second port (17a and 19a) in the first position.

16 Crossover stab 12 includes an annulus access channel 18 facilitating fluid
17 communication to a downhole annulus 21 between the production tubing 7 and the
18 innermost casing (tubing annulus not shown). Annulus access channel 18 is substantially
19 longitudinal through tubing hanger 4, crossover stab 12, crossover assembly 10, and tree
20 2. Annulus access channel 18 is typical of a plurality of annulus access channels 18
21 shown in cross-section in Figures 25a - 25d. In the section shown in Figures 25a and
22 25b, the first portion of annulus access channels 18 are designated 18a and are arranged

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1 interior to the crossover assembly between the interior wall 200 and the exterior diameter
2 202. The number and size of annular access channels 18a is a function of the flow
3 capability desired. Typically the equivalent flow area of the combination of annulus
4 access channels 18a is at least 1.5 inches, however this equivalent flow area may vary
5 according to the particular operation. The equivalent flow area may be determined by
6 operational standards to provide sufficient flow to, for example, kill a well with heavy
7 fluids in the event of an emergency. Annulus access channels 18a converge to a common
8 eccentric connector 204 which provides for fluid communication from each of annulus
9 access channels 18a to continue through another plurality of larger annulus access
10 channels, for example the three larger annulus access channels 18b shown in Figures 25a
11 , 25c, and 25d. FIG 25c is a view in the upward direction of the section shown in Figure
12 25a, which is in the opposite direction of same section shown in Figure 25b. Annulus
13 access channels 18a and 18b advantageously provide an equivalent flow area to
14 operationally manage the well while also allowing for a single bore tubing hanger.
15 Similar channels may be part of the crossover tree system to provide for chemical
16 injection downhole, or to provide communication with downhole equipment such as
17 pressure and temperature sensors. Those skilled in the art will appreciate that the
18 disclosure of the annulus communication system is applicable to many other types of
19 downhole communication. In the exemplary embodiment shown, chemical channels 23
20 extend through crossover assembly 10 to facilitate chemical injection into production
21 tubing 7 in much the same way as annulus access channels 18. In the embodiment
22 shown, the plurality of chemical channels 23 provide a minimum equivalent flow area of

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1 0.375 inches to provide adequate flow to the production bore as necessary. It will be
2 understood by one of skill in the art with the benefit of this disclosure, however, that
3 other equivalent flow areas deviating substantially in either direction from 0.375 inches
4 can be obtained as required for the particular application.

5 One or more annulus valves 20 may isolate the sections of annulus access channel
6 18 between the tree 2 and the crossover assembly 10. Annulus valve 20 is shown in
7 Figure 1 exterior to the tree body, but it may be located anywhere along annulus access
8 channel 18. A second annulus valve 21 may also be used as shown in Figures 1 and 16.
9 While the annulus valves and piping are shown with flanged connections to the tree 2,
10 other types of connections can be substituted, or portions of the annulus piping or valves
11 may be integral to the tree body as shown in Figure 30.

12 Annulus access channel 18 extends through a radial bore 32 in tree 2, continues
13 outside the body of tree 2, then re-enters the body of tree 2 and continues substantially
14 longitudinal with the proximal end of tree 2. A retractable radially extending annulus
15 stab assembly 36 extends between radial annulus bore 32 in tree 2 and crossover
16 assembly 10. The retractability of an annulus stab 35 advantageously allows for
17 independent installation and retrieval of tubing hanger 4, crossover assembly 10, and the
18 tree 2. Annulus access channel 18 terminates at a proximal annulus port 34 which
19 facilitates fluid communication between the tubing annulus and the surface. While
20 annulus port 34 is shown above the crossover assembly 10, it may be located adjacent or
21 below the crossover assembly.

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1 Annulus stab 35 may be operable by hydraulic or electric actuation, or it may be
2 mechanically operated. In the embodiment shown, annulus stab 36 is operated
3 mechanically. The details of the annulus stab assembly 36 are found in Figures 26-29.
4 For example, annulus stab 35 may be operable by ROV (not shown). The ROV may be a
5 standard remote operated vehicle or it may be any other remotely operated vehicle. The
6 ROV provides rotational movement to annulus stab mechanism 210 to extend and/or
7 retract annulus stab 35 between crossover assembly 10 and tree 2. Annulus stab
8 mechanism 210 shown in Figures 26-29 includes first and second shafts 212 and 214
9 extending from the annulus stab mechanism. Distal end 216 of second shaft 214 is
10 adapted to connect to an ROV. Proximal end 218 of second shaft 214 is operatively
11 connected to a pair of bevel gears 220 and 222 which are approximately 90 degrees out of
12 phase with one another. Therefore, rotation of second shaft 214 is translated 90 degrees
13 to rotate first shaft 212. In an alternative embodiment, first shaft 212 is rotated directly
14 without the use of a second shaft or set of gears. First shaft 212 is threadedly connected
15 to annulus stab 35. Annulus stab 35 includes an anti-rotation key 224 which prevents the
16 annulus stab from rotating with first shaft 212. Therefore, as first shaft 212 rotates, the
17 rotational movement is translated via the threaded connection with annulus stab 35 into
18 strictly axial movement of the annulus stab. Upon connection between second shaft 214
19 and the ROV, rotation of the second shaft may ultimately accomplish the extension or
20 retraction of annulus stab 35 into and/or out of engagement with crossover assembly 10.
21 Alternatively, annulus stab 35 may be hydraulically or electrically extended and retracted
22 (not shown). Figure 36 shows in perspective view the annulus stab mechanism 36.

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1 Crossover stab 12 also includes a downhole safety valve control assembly 92
2 which is in communication with a safety valve access channel 94 through crossover stab
3 12. As shown in more detail in Figure 15A, gallery seals 14 prevent the flow of
4 hydraulic fluid associated with safety valve access channel 94 substantially above or
5 below the channel. When the sliding valve 16 is in the open or down position as shown
6 in Figure 15B, channel 94 aligns with a channel in the tubing hanger 4 (not shown) to
7 provide hydraulic communication downhole. When the sliding valve 16 is in the closed
8 or up position as shown in Figure 15A, channel 94 is not aligned with the channel in the
9 tubing hanger 4 (not shown) and hydraulic communication is not present (putting the
10 downhole safety valve into its fail-closed position). As such, downhole safety valve
11 control assembly 94 and safety valve access channel 94 allow the operator to open or
12 close the downhole safety valve 9 (shown in Figure 10) as necessary.

13 A crossover seal 38 seals the annulus between crossover assembly 10 and tree 2
14 and may serve as a second barrier to any possible leaks across crossover seal 40 in
15 crossover assembly 10. Seal 38 may be comprise metal-to-metal sealing elements or may
16 comprise resilient sealing elements.

17 In the embodiment of Figure 1, a wireline plug 24 is disposed within crossover
18 assembly 10. A second wireline plug 26 is also disposed within crossover assembly 10.
19 Wireline plugs 24 and 26 provide a multi seal between the production fluids entering
20 tubing hanger 4, and cap assembly 42. Plugs 24 and 26 may comprise mechanical or
21 hydraulic plugs, may be retrievable using wireline, coiled tubing, or pipe, or may be

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1 valves or other closures which are known in the art. In the embodiments of Figures 10
2 through 21, both closures are installed in crossover assembly 10.

3 At least a portion crossover assembly 10 and tubing hanger 4 are located radially
4 interior to tree 2. Crossover assembly 10 has associated lock down ring 30 to position the
5 crossover assembly securely within tree 2 and to prevent dislocation after the assembly is
6 landed and locked.

7 In one embodiment, tree 2 includes a radially extending production stab assembly
8 44. Production stab assembly 44 includes a tree bore 46, which is aligned with a
9 crossover bore 48 in crossover assembly 10. A production stab 50 extends between
10 crossover bore 48 and tree bore 46 in the position shown in Figure 1. A plurality of
11 production seals 52 seal between the production stab 50 and bores 46 and 48. Production
12 stab 50 is retractable as described below. One or more production valves, such as valve
13 54 shown, may be attached to production stab assembly 44 to control the flow of
14 produced hydrocarbons. Figure 10 shows a general arrangement including production
15 master valve (PMV) 54 and production wing valve (PWV) 99. One or more of valves 54
16 and 99 may be flanged and bolted to the tree 2, as is shown for valve 54 in Figure 1, or
17 one or more of the valves may be integral to a valve block or to the tree body as shown in
18 Figure 30. The embodiment of Figure 2 shows production valve 54 adjacent production
19 stab assembly 44, but it will be understood that production valve 54 may be integral to
20 the production stab assembly as shown in Figure 30.

21 Similar to annulus stab 35, production stab 50 may be operable by hydraulic or
22 electric actuation, or it may be mechanically operated. In the embodiment shown,

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1 production stab 50 is operated mechanically. For example, production stab 50 may be
2 operable by an ROV (not shown). The ROV provides rotational movement to a
3 production stab mechanism 230 to extend and/or retract production stab 50 between
4 crossover assembly 10 and tree 2. Production stab mechanism 230 shown in FIGs 26-29
5 includes first and second shafts 232 and 234 extending from the production stab
6 mechanism. Distal end 236 of second shaft 234 is adapted to connect to an ROV.
7 Proximal end 238 of second shaft 234 is operatively connected to a pair of bevel gears
8 220 and 222 which are approximately 90 degrees out of phase with one another.
9 Therefore, rotation of second shaft 234 is translated 90 degrees to rotate first shaft 232.
10 In an alternative embodiment, first shaft 232 is rotated directly without the use of a
11 second shaft or set of gears. First shaft 232 is threadedly connected to production stab
12 50. Production stab 50 includes an anti-rotation key 240 which prevents the production
13 stab from rotating with first shaft 232. Therefore, as first shaft 232 rotates, the rotational
14 movement is translated via the threaded connection with production stab 50 into strictly
15 axial movement of the production stab. Upon connection between second shaft 234 and
16 the ROV, rotation of the second shaft may ultimately accomplish the extension or
17 retraction of production stab 50 into and/or out of engagement with crossover assembly
18 10. Alternatively, production stab 50 may be hydraulically or electrically extended and
19 retracted (not shown). Second shafts 234 and 214 may extend through a standard ROV
20 panel 242, along with an alignment pin shaft 244. Figure 35 shows in perspective view
21 the annulus stab mechanism 36.

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1 With the assembly as shown in Figure 1, production fluids may enter tubing
2 hanger 4 from the wellbore and continue through a portion of crossover assembly 10.
3 The production fluids are then directed through crossover bore 48 as wireline plug 26
4 inhibits further progression up through crossover assembly 10. Production fluids
5 continue through tree bore 46 and into the radially extending production stab assembly
6 44. When production valve 54 is open, production fluids then continue into a flow line
7 246 for further transportation to a desired location. An operator also has access,
8 according to the embodiment shown in Figure 1, to the annulus of the wellbore tubing
9 through annulus access channel 18. The access to the annulus may be important, for
10 example, to allow an operator to circulate fluids, to relieve pressure in the annulus, or to
11 bullhead the well for example. Should there be any leakage past either wireline plug 26
12 or crossover seal 40, a redundant set of seals on wireline plug 24 and seal 41 prevent
13 further leaking. A perspective view of the apparatus of Figure 1 is shown in Figure 38.

14 Referring next to Figures 2 and 2b, one of many sequences of installation,
15 retrieval, or workover that are possible in accordance with the invention is described.
16 Figures 2, 2b and 12 depict the installation and/or retrieval of tubing hanger 4 within
17 wellhead 6. Generally, tubing hanger 4 is installed while a blowout preventor (BOP)
18 stack 60 is attached to wellhead 6 or to the tree 2. BOP stack 60 is conventional and well
19 known to one of skill in the art with the benefit of this disclosure. Referring to Figure 3,
20 with BOP stack 60 in place, tubing hanger 4 and crossover stab 12 are inserted into or
21 retrieved from wellhead 6. Crossover stab 12 is in the working or down position as
22 shown in Figures 1 and 2b. Tubing hanger 4 and crossover stab 12 are attached to a multi

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1 purpose running tool 62. Multi purpose running tool 62 is also shown in FIG 39. In
2 Figure 2, however, the christmas tree 2 has also been installed and only the tubing hanger
3 has been installed without the crossover stab. In some embodiments tubing hanger 4
4 includes tubing hanger collet fingers 64, which are engaged with a collet 66 at the distal
5 end of multi purpose running tool 62 during installation and/or retrieval of tubing hanger
6 4. When tubing hanger 4 is being installed, the hanger continues downhole via multi
7 purpose running tool 62 until it engages wellhead shoulder 8. When tubing hanger 4
8 engages wellhead shoulder 8, tubing hanger lockdown ring 56 locks the hanger in place
9 and multi purpose running tool 62 may be returned to surface.

10 Referring next to Figures 3 and 13, with tubing hanger 4 positioned within
11 wellbore 6, crossover stab 12 is removed, allowing the sliding valve 16 to be in the closed
12 or up position. A wireline plug 68 or other closure is set inside the tubing hanger through
13 BOP stack 60. The BOP stack is then retrieved and a temporary abandonment/debris cap
14 assembly 42 is installed and attached to wellhead 6 in the position shown in Figures 3 and
15 13. Tubing hanger sliding valve 16 is in the up or sealed off position in this sequence to
16 prevent flow through the annular access or chemical injection porting, as the assembly
17 awaits the installation of tree 2.

18 Referring next to Figure 5, the temporary abandonment/debris cap assembly 42
19 and wireline plug 68 have been removed and fully assembled tree 2 is installed. Tree 2 is
20 run on tree running tool 70 with crossover assembly 10, crossover stab 12, and plug 24 in
21 place inside tubing hanger 4. Crossover stab 12 is in the up or running position and
22 tubing hanger sliding valve 16 is in the up or sealed position, which seals off the tubing

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1 annulus communication, as well as other downhole communication such as the safety
2 valve 9 and injection lines at the sliding valve 16. Tree running tool 70 is attached to the
3 exterior of tree body 2 via tree running tool lock down ring 72. The complete tree
4 assembly 2 is run until tree connector lock down ring 58 engages with wellbore 6 and the
5 tree is secured in the position shown in Figure 5.

6 Referring next to Figure 6, tree assembly 2 is shown in sequence wherein
7 preparation is made for retrieving crossover assembly 10. The preparation for retrieval of
8 crossover assembly 10 comprises reinstalling BOP stack. In the sequence shown in
9 Figure 6, BOP stack 60 is being run in and lock down ring 74 has not yet engaged tree 2.
10 In Figure 7, BOP 60 is installed and connected to the proximal end of tree 2. BOP lock
11 down rings 74 are engaged with tree 2 at the proximal end of the tree. If any wireline
12 plugs have been set in the crossover assembly they may be retrieved and wireline plug 68
13 inside tubing 4 is set, in preparation for retrieving crossover assembly 10.

14 As shown in Figure 7, the multi purpose running tool 62 may be inserted through
15 BOP stack 60 to retrieve crossover assembly 10. Multi purpose running tool is shown
16 attached to crossover assembly 10. In the embodiment shown in Figure 7, the attachment
17 between crossover assembly 10 and multi purpose running tool 62 is facilitated by an
18 crossover assembly collet finger 76 engaged with collet 66 of multi purpose running tool
19 62. Crossover assembly collet finger 76 may be mounted on an exterior surface of
20 crossover assembly 10 as shown in the Figures. With the multi purpose running tool 62
21 attached to crossover assembly 10, the running tool and tree cap may be either retrieved
22 or installed. When crossover assembly 10 is installed, its operational position relative to

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1 tree 2 is facilitated by crossover assembly lock down ring 28, which is engageable with
2 tree 2 as discussed above. In addition, during installation and retrieval of crossover
3 assembly 10, crossover stab 12 is in the up or installation/retrieval position as shown.

4 The engagement of collet fingers 76 and collet 66 constitute one mechanism of
5 attachment between crossover assembly 10 and running tool 62. Other alternative
6 attachment mechanism may be used. During installation and retrieval of crossover
7 assembly 10, sliding sleeve 16 is in the up or installation/retrieval position as shown. In
8 addition, production stab 50 and annulus stab 35 are retracted before installation or
9 retrieval proceeds. The retraction of the production stab 50 and annulus stab 35 is
10 accomplished by a mechanical ROV in the preferred embodiment, but other means for
11 actuation including, but not limited to, hydraulic and/or electric, may be used. [If a
12 hydraulic system is used, production stab 50 and annulus stab 35 may be normally biased
13 to the retracted positions with the extension of each accomplished by hydraulic fluid.
14 Alternatively, production stab 50 and annulus stab 35 may be motivated to their
15 respective extended and retracted positions with hydraulic pressure without a bias.
16 Hydraulic control lines (not shown) extending to sealed void areas between the stab
17 assembly 44 and the production stab 50, or between the annulus stab 35 and the annulus
18 piping, are one means of such control. In a preferred embodiment, one set of hydraulic
19 lines will control both sets of stabs. Preferably, production stab 50 and annulus stab 35
20 may be actuated by mechanical means such as the production stab mechanism 230. After
21 installation, and after crossover assembly 10 is positioned in the tree with crossover bore

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1 48 aligned with tree bore 46, annulus stab 35 and production stab 50 are extended to the
2 position shown in Figure 1.

3 Referring next to Figure 8, the tree assembly is shown without crossover
4 assembly 10. In this configuration, which may be before installation of crossover
5 assembly 10, or after retrieval of the same, full bore access to the wellbore through tubing
6 hanger 4 is available. Full bore access advantageously enables workover of the well or
7 other repairs and maintenance. Tubing hanger sliding valve 16 is in the up or sealed
8 position in full bore access position to seal off access to the tubing annulus (not shown).
9 Wireline plug 68 is also in place within tubing hanger 4 in this configuration. In order to
10 accomplish the installation and/or retrieval of the crossover assembly, however, the
11 production stab 50 and annulus stab 35 must first be retracted as shown.

12 Referring next to Figure 31, the crossover assembly 10 is being installed through
13 BOP 60.

14 Referring next to Figure 32, crossover assembly 10 has been installed by multi
15 purpose running tool 62 and crossover stab 12 extended to force sliding valve 16 into the
16 open position. Wireline plugs 24 and 26 may then be set in anticipation of production.
17 Alternatively, in a retrieval operation, wireline plugs may be retrieved and crossover
18 assembly 10 and crossover stab 12 may be retrieved as well.

19 Referring next to Figure 33, an installation/retrieval sequence for christmas tree 2
20 is shown. Christmas tree 2 is shown running on a tree running tool 250. Tree running
21 tool 250 may be used similarly to retrieve tree 2.

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1 Referring next to Figures 34 and 35, a detail of the interface between crossover
2 assembly 10 and tubing hanger 4 is shown. The flow path of annulus access channels 18
3 are more clearly seen as it extends through the crossover assembly and to the tubing
4 hanger via an annulus cavity 252. Likewise, the flow path of the chemical injection
5 channels 23 are more clearly seen as they extend through the crossover assembly and to
6 the tubing hanger via a second cavity 254. Sliding valve 16 facilitates and/or prevents the
7 flow of through all of the annulus access channels 18 and chemical injection channels 23.

8 In some embodiments of the present invention the engagement between crossover
9 assembly 10 and tubing hanger 4 includes one or more electrical contacts 260. As shown
10 in Figure 37-38, the electrical contacts may be separated isolated by a number of seals
11 262.

12 Referring next to Figures 9a - 9c, it can be seen that an integral orientation helix
13 82 may be included on crossover assembly 10. Orientation helix 82 shaped such that
14 upon installation of crossover assembly 10, the assembly is directed into the correct
15 orientation position with crossover bore 48 aligned with tree bore 46. Orientation helixes
16 and their use are well known in the art. Alignment pin 270 extending through tree 2
17 engages helix 82 and directs the crossover assembly to the desired orientation.

18 The present invention thus advantageously facilitates a horizontal tree and tubing
19 hanger to each be independently retrievable with full-bore wellhead access.

20 Referring next to Figure 10, a hydraulic schematic for the crossover tree system
21 (designated CTS in Figures 10 through 21) in accordance with one embodiment of the
22 invention in the production mode is disclosed. The production system valving may

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1 include a production master valve 54 and optionally a production wing valve 99 to
2 facilitate control of the production fluids from the wellbore. Access to the tubing annulus
3 may also be facilitated by the valving scheme shown in Figure 10. An annulus master
4 valve 20 facilitates primary access to the annulus. An annulus wing valve 21 may allow
5 the flow of annular fluids to an external connection or may be the means by which
6 annular fluids are introduced through an external connection. In series with the annular
7 master valve may be an annulus circulation valve 100 to regulate flow and/or pressure in
8 the annulus and provide a communication with the longitudinal throughbore of tree 2. In
9 addition, a crossover valve 102 may allow the operator to open or close fluid
10 communication between the production line and the annulus.

11 Referring next to Figure 12, one of a second set of sequences in accordance with
12 the invention is shown. Figure 12 depicts the installation and/or retrieval of tubing
13 hanger 4 within wellhead 6. Generally, tubing hanger 4 is installed while a blowout
14 preventor (BOP) stack 60 is attached to wellhead 6. BOP stack 60 is conventional and
15 well known to one of skill in the art. With BOP stack 60 in place, tubing hanger 4 and
16 crossover stab 12 are inserted into or retrieved from wellhead 6. Crossover stab 12 is in
17 the working or down position as shown in Figures 1 and 2. Tubing hanger 4 and
18 crossover stab 12 are attached to multi purpose running tool 62. In some embodiments
19 tubing hanger 4 includes tubing hanger collet fingers 64, which are engaged with a collet
20 66 at the distal end of multi purpose running tool 62 during installation and/or retrieval of
21 tubing hanger 4. When tubing hanger 4 is being installed, the hanger continues downhole
22 via multi purpose running tool 62 until it engages wellhead shoulder 8. When tubing

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1 hanger 4 engages wellhead shoulder 8, tubing hanger lockdown ring 56 locks the hanger
2 in place and multi purpose running tool 62 may be returned to surface. In a preferred
3 embodiment, tubing hanger 4 is a non-oriented tubing hanger, although oriented tubing
4 hangers may be provided.

5 Referring next to Figure 13, with tubing hanger 4 positioned within wellbore 6,
6 crossover stab 12 is removed and a wireline plug 68 or other closure is set inside the
7 tubing hanger through BOP stack 60. The BOP stack may be retrieved and a temporary
8 abandonment/debris cap assembly 42 may be installed and attached to wellhead 6 in the
9 position shown in Figure 13. Tubing hanger sliding valve 16 is in the up or sealed off
10 position in this sequence to prevent flow through the annular access or chemical injection
11 porting, as the assembly awaits the installation of tree 2.

12 Referring next to Figure 14, the temporary abandonment/debris cap assembly 42,
13 wireline plug 68 remains in place, and fully assembled tree 2 is installed. Tree 2 is run on
14 tree running tool 70 with internal tree cap 22, crossover assembly 10, and crossover stab
15 12 inside tree body 2. Plugs 24 and 26 are not installed inside tree body 2 in this
16 sequence. Crossover stab 12 is in the up or running position and tubing hanger sliding
17 valve 16 is in the up or sealed position, which seals off the tubing annulus (not shown) at
18 the valve. Tree running tool 70 is attached to the exterior of tree body 2 via tree running
19 tool lock down ring 72. The complete tree assembly 2 is run until tree lock down ring 58
20 engages with wellbore 6 and the tree is secured in the position shown in Figure 14.

21 Referring next to Figures 15a and 15b, a detailed view of crossover stab assembly
22 12 is shown. In Figure 15a, crossover stab 12 is in the up or running position and tubing

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1 hanger sliding valve 16 is in the up or sealed position, which seals off the tubing annulus
2 communication, chemical injection lines, and the downhole safety valve hydraulics as
3 tree 2 is installed.

4 For example, Figure 15a shows that in the up or running position, first ports 17
5 (the annulus communication ports) in sliding valve 16 do not align with first ports 17a in
6 tubing hanger 4. It will be understood to those of skill in the art that port 17a in the
7 tubing hanger 4 may be one of several ports radially spaced around the tubing hanger,
8 and extend down through the tubing hanger body to the tubing annulus. First ports 17a in
9 tubing hanger 4, which may be arranged about the inner circumference of the tubing
10 hanger, are preferably arranged equidistantly around the inner circumference of tubing
11 hanger 4. By sizing the ports properly and selecting the appropriate number of ports first
12 ports 17a provide a fluid communication path with sufficient flow area to the tubing
13 annulus. The number of ports and/or the size of the ports may vary depending on the use
14 and field characteristics.

15 Similarly, second ports 19a may provide a fluid communication path for chemical
16 injection lines downhole for facilitating chemical insertions into the production and/or the
17 formation. It will be appreciated that any number of porting arrangements and
18 communications downhole may be provided.

19 The communications paths facilitated by first ports 17a and second ports 19a are,
20 however, sealed off from respective first and second ports 17 and 19 in Figure 15a.
21 When tree 2 has been set, crossover stab 12 may be extended into tubing hanger 4 to the
22 position shown in Figure 15b until first ports 17 and second ports 19 in valve 16 align

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1 with first ports 17a and second ports 19a in tubing hanger 4, respectively. Alignment is
2 accomplished when the shoulder 13 of shuttle valve 16 contacts ledge 90 of tubing
3 hanger 4.

4 Figure 16 depicts the next sequence in which the tubing hanger plug 68 is
5 retrieved on wireline and crossover wireline plugs 24 and 26 are installed as shown. Tree
6 running tool 70 (not shown in Figure 16) may then be retrieved and an ROV may install
7 the temporary abandonment/debris cap 42.

8 An optional set of sequences are shown in Figures 17-21 and are described as
9 follows. Referring to Figure 1, tree 2 may be run with an empty body on tree running
10 tool 70. In this sequence, the internal tree cap, crossover assembly 10, crossover stab 12,
11 and plugs 24 and 26 are not in place inside tree body 2. Tree 2 is locked onto wellhead 6
12 as described previously.

13 Referring next to Figure 18, BOP stack 60 is run and locked onto tree 2 via BOP
14 lockdown ring 74 which mates with matching profile 95 on tree 2. Tubing hanger 4 may
15 be run in on multi use running tool 62 as described above. No orientation apparatus is
16 required with the running of the tubing hanger. A wireline plug 68 may be installed in
17 the tubing hanger (not shown in Figure 18).

18 Referring next to Figures 19a and 19b, crossover assembly 10 may be run on
19 multi use running tool 62. Crossover assembly 10 self-oriens within tree 2 with the aid
20 of an orientation helix as described above and shown in Figure 9. As shown in Figure
21 19b, which is a detail of the multi use running tool 62, the crossover stab 12 (not shown
22 in Figure 19b) may be replaced by a bore protector

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1 Figures 20a and 20b, similar to figures 15a and 15b, show the extension of
2 crossover stab 12. In Figure 20a, crossover stab 12 is in the up or running position and
3 tubing hanger sliding valve 16 is in the up or sealed position, which seals off the tubing
4 annulus (not shown) at the valve as tree 2 is installed. Figure 20a shows that in the up or
5 running position, upper ports 17 and lower ports 19 in sliding valve 16 do not align with
6 upper ports 17a and lower ports 19a in tubing hanger 4. Upper ports 17a in tubing hanger
7 4, which may be arranged about the inner circumference of the tubing hanger, are
8 preferably arranged equidistantly around the inner circumference of tubing hanger 4.
9 Upper ports 17a provide a fluid communication path to the tubing annulus (not shown).
10 Lower ports 19a provide a fluid communication path to the downhole tubing (not shown)
11 for facilitating chemical insertions into the production formation. The communications
12 paths facilitated by upper ports 17a and lower ports 19a are, however, sealed off from
13 respective upper and lower ports 17 and 19 as shown in Figure 20a. When tree 2 has
14 been set, crossover stab 12 may be extended to the position shown in Figure 20b until
15 upper ports 17 and lower ports 19 in valve 16 align with upper ports 17a and lower ports
16 19a in tubing hanger 4, respectively. Alignment is accomplished when the shoulder 13 of
17 shuttle valve 16 contacts ledge 90 of tubing hanger 4.

18 Referring next to Figure 21, the CTS is shown completely installed. The optional
19 sequence leading up to Figure 21 as shown includes retrieving tubing hanger plug 68 (not
20 shown in Figure 21), installing crossover plugs 24 and 26 on wireline, retrieving BOP
21 stack 60 (not shown in Figure 21) and installing temporary abandonment/debris cap 42.

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1 In view of the above disclosure, one of ordinary skill in the art should understand
2 and appreciate that one illustrative embodiment of the present invention includes a
3 subterranean oil or gas well assembly that includes: a wellhead; a christmas tree coupled
4 to the wellhead; and a tubing hanger landed within the wellhead. A sliding valve is
5 disposed within the tubing hanger to selectively allow fluid communication between a
6 first port in the sliding valve and a first port in the tubing hanger. A crossover assembly
7 is landed within the tree body, and; a crossover stab is disposed within the crossover
8 assembly and adapted to translate the sliding valve between open and closed positions.
9 In a preferred version of the present illustrative embodiment, the tubing hanger is
10 substantially concentric with the wellhead. Preferably the tubing hanger is a production
11 tubing hanger with a production tubing suspended therefrom. The tubing hanger can also
12 include an annulus access channel extending between the first port in the tubing hanger
13 and an annulus, the annulus being defined between the production tubing and an
14 innermost casing. The christmas tree preferably includes a radial annulus bore and a
15 radial production bore. Alternatively the christmas tree includes an integral production
16 bore valve. In one embodiment the illustrative assembly includes a plurality of annulus
17 access channels arranged about the tubing hanger and extending between the annulus and
18 a plurality of first ports. Preferably the plurality of annulus access channels converge to a
19 common eccentric connector. More preferably the annulus access channels reduce in
20 number between the eccentric connector and the christmas tree radial annulus bore. In
21 one particularly preferred embodiment, the plurality of annulus access channels provides
22 an equivalent flow area of at least 1.5 inches. The assembly of the present illustrative
23 embodiment can be designed such that the crossover stab further defines the annulus
24 access channel. The crossover stab preferably defines the plurality of annulus access
25 channels.

26 The above described illustrative embodiment can also include a biasing member
27 that is disposed between the tubing hanger and the sliding valve. The biasing member
28 biases the sliding valve to the closed position. The crossover assembly further defines the
29 annulus access channel and preferably the crossover assembly further defines more than

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1 one annulus access channel. In one illustrative embodiment, the sliding valve facilitates
2 fluid communication between the annulus access channel defined by the crossover
3 assembly and the annulus access channel defined by the crossover stab. The illustrative
4 embodiment of the present invention can alternatively include a christmas tree that
5 further defines the annulus access channel. Preferably the crossover assembly further
6 includes a radial annulus bore and a radial production bore. More preferably, the
7 crossover assembly further includes an orientation helix for facilitating the alignment of
8 the crossover radial annulus bore with the tree radial annulus bore and the crossover
9 radial production bore with the tree radial production bore.

10 It is also contemplated that the assembly of the present invention includes an
11 extendable/retractable production stab, the production stab being extendable between the
12 tree radial production bore and the crossover radial production bore. In one illustrative
13 embodiment including the extendable/retractable annulus stab, the annulus stab is
14 extendable between the tree radial annulus bore and the crossover radial annulus bore.
15 The tree and the crossover assembly are preferably independently retrievable when the
16 annulus stab is retracted. In a similar manner it is contemplated that the tree and the
17 crossover assembly are independently retrievable when the production stab is retracted.
18 The production stab mechanism includes a first shaft, a second shaft operatively
19 connected to the first shaft by a pair of bevel gears, and a threaded connection between
20 production stab and the first shaft. Preferably the mechanism further includes an anti-
21 rotation key to prevent the production stab from rotating with the first shaft. The
22 assembly of the present invention may also include an annulus stab mechanism in which
23 the mechanism includes a first shaft, a second shaft operatively connected to the first
24 shaft by a pair of bevel gears, and a threaded connection between annulus stab and the
25 first shaft. In one preferred embodiment, the mechanism further includes an anti-rotation
26 key to prevent the annulus stab from rotating with the first shaft. The assembly of the
27 present illustrative embodiment alternatively includes a second port in the sliding valve to
28 selectively allow fluid communication of chemicals between the second port in the
29 sliding valve and a second port in the tubing hanger. In such an illustrative assembly,

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1 the tubing hanger includes a chemical injection channel extending between the second
2 port in the tubing hanger and a production tubing. A plurality of chemical injection
3 channels is contemplated and may be arranged about the tubing hanger and extending
4 between the production tubing and a plurality of second ports. In one illustrative
5 embodiment, the plurality of chemical injection channels converge to a common
6 eccentric connector. Preferably the plurality of chemical injection channels reduce in
7 number between the eccentric connector and a christmas tree chemical channel and more
8 preferably the plurality of chemical injection channels provides an equivalent flow area
9 of at least 0.375 inches. The crossover stab, in one illustrative embodiment, further
10 defines the chemical injection channel and it is preferred that it defines a plurality of
11 chemical injection channels. Alternatively the crossover assembly can define the
12 chemical injection channel and preferably the crossover assembly defines the one or more
13 chemical injection channels. In one illustrative embodiment, the sliding valve facilitates
14 fluid communication between the chemical injection channel defined by the crossover
15 assembly and the chemical injection channel defined by the crossover stab.
16 Alternatively, the christmas tree can further define the chemical injection channel.

17 As is presently contemplated, the present invention may also encompass a
18 subterranean oil or gas well assembly that includes: a wellhead; a christmas tree coupled
19 to the wellhead; and a single bore tubing hanger landed within the wellhead. The tubing
20 hanger has a production tubing suspended from it. The single bore tubing hanger further
21 includes a plurality of first closable ports therein, the first closable ports facilitating fluid
22 communication to an annulus defined by the production tubing and an innermost casing.
23 The single bore tubing hanger further includes a plurality of tubing hanger annulus access
24 channels extending from at least one of the plurality of first closable ports to the annulus.
25 The illustrative assembly optionally includes a plurality of uphole annulus access
26 channels in which the plurality of first closable ports are correspondingly alignable with
27 the uphole annulus access channels to facilitate fluid communication between the uphole
28 annulus access channels and the tubing hanger annulus access channels. The illustrative
29 assembly can alternatively include a crossover assembly landed within the tree, wherein

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1 the uphole annulus access channels extend through aligned radial bores in the crossover
2 assembly and the christmas tree. In one such embodiment the uphole annulus access
3 channels extend longitudinally through the christmas tree. The assembly can be
4 embodied such that the crossover assembly further includes a crossover stab and the
5 plurality of first closable ports further comprises a sliding valve. The sliding valve is
6 operable to open and close the first closable ports to selectively allow fluid
7 communication between the tubing hanger annulus access channels and the uphole
8 annulus access channels. Alternatively, the plurality of uphole annulus access channels
9 can converge to a common eccentric connector, such that the number of uphole annulus
10 access channels is reduced between the eccentric connector and the christmas tree. The
11 present illustrative assembly can be made such that the single bore tubing hanger further
12 includes a second plurality of closable ports and a plurality of tubing hanger chemical
13 injection channels extending from the second plurality of closable ports, through the
14 tubing hanger, and to the tubing hanger bore. The assembly may alternatively be made to
15 include a plurality of uphole chemical injection channels, in which the plurality of first
16 closable ports are correspondingly alignable with the uphole chemical injection channels
17 to facilitate fluid communication between the uphole chemical injection channels and the
18 tubing hanger chemical injection channels. The crossover assembly can be landed within
19 the tree, such that the uphole chemical injection channels extend through aligned
20 longitudinal bores arranged about the crossover assembly and the christmas tree. The
21 crossover assembly can also include a crossover stab and the plurality of second closable
22 ports further comprises a sliding valve. In such an illustrative embodiment, the sliding
23 valve is operable to open and close the second closable ports to selectively allow fluid
24 communication between the tubing hanger chemical injection channels and the uphole
25 chemical injection channels. In another illustrative embodiment of the present invention,
26 the plurality of uphole chemical injection channels converge to a common eccentric
27 connector, and wherein the number of uphole chemical injection channels is reduced
28 between the eccentric connector and the christmas tree.

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1 The present invention also contemplates a method of servicing a subterranean
2 well. Such an illustrative method includes the steps of: providing a wellhead preferably
3 with a BOP stack mounted onto the wellhead; installing a tubing hanger the wellhead and
4 installing a christmas tree with an internal crossover assembly mounted therein onto the
5 wellhead. In one embodiment, the tubing hanger includes: a bore concentric with the
6 wellhead and a plurality of channels bored longitudinally partially therethrough, the
7 plurality of channels being spaced around the circumference of the tubing hanger. In
8 another embodiment, the tubing hanger further includes a plurality of first ports and a
9 plurality of second ports and a sliding valve for selectively opening and closing the first
10 and second pluralities of ports. In another embodiment, the christmas tree includes an
11 extendable/retractable stab between radial bores in the crossover assembly and christmas
12 tree. The illustrative method may also include the step of retracting the stab. Optionally,
13 the method may include the step of retrieving the christmas tree separately from the
14 tubing hanger. In another illustrative embodiment the method includes the step of
15 retrieving the crossover assembly and the tubing hanger while the christmas tree remains
16 connected to the wellhead. In yet another illustrative embodiment, the method may
17 include the step of opening the sliding valve by inserting a crossover stab to position the
18 sliding valve in an open position.

19 One of ordinary skill in the art should also appreciate that the present invention
20 includes a subsea wellbore production apparatus with a side-production bore christmas
21 tree, a production tubing hanger, and an internal crossover assembly. It should be
22 appreciated that the improvement to such an apparatus includes a production stab that is
23 retractable into the christmas tree and extendable between radial bores in the christmas
24 tree and the crossover assembly. In such an apparatus, the stab provides a sealed flow
25 path between the crossover assembly and the christmas tree. Preferably the production
26 stab further includes an actuation mechanism. The actuation mechanism includes: a first
27 rotatable shaft in threaded engagement with the production stab; and a rotational key lock
28 preventing rotation of the production stab; such that rotation of the first shaft is translated
29 into axial movement of the production stab. The apparatus may also include a second

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1 rotatable shaft operatively connected to the first rotational shaft by gears, wherein
2 rotation of the second rotatable shaft is translated into rotation of the first rotational shaft.
3 The illustrative apparatus may optionally include an annulus stab which is retractable into
4 the christmas tree and extendable between second radial bores in the christmas tree and
5 the crossover assembly. The apparatus preferably has a plurality of annulus access
6 channels spaced around the tubing hanger and the crossover assembly, and wherein the
7 annulus access channels communicate with a christmas tree annulus channel. In an
8 alternative embodiment, the apparatus includes a plurality of chemical injection channels
9 spaced around the tubing hanger and the crossover assembly, and wherein the chemical
10 injection channels communicate with a christmas tree chemical injection channel.

11 While the present invention has been particularly shown and described with
12 reference to a particular illustrative and preferred embodiments thereof, it will be
13 understood by those skilled in the art that various changes in form and details may be
14 made without departing from the scope of the invention. The above-described
15 embodiments are intended to be merely illustrative, and should not be considered as
16 limiting the scope of the present invention which is defined in the following claims.

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CLAIMS:

1. A subterranean oil or gas well assembly comprising:
 - a) a wellhead;
 - b) a christmas tree coupled to the wellhead;
 - 5 c) a tubing hanger landed within the wellhead;
 - d) a sliding valve disposed within the tubing hanger to selectively allow fluid communication between a first port in the sliding valve and a first port in the tubing hanger;
 - e) a crossover assembly landed within the tree body, and;
 - 10 f) a crossover stab disposed within the crossover assembly and adapted to translate the sliding valve between open and closed positions.
2. The assembly of claim 1 wherein the tubing hanger is substantially concentric with the wellhead.
3. The assembly of claim 1 wherein the tubing hanger is a production tubing hanger with a
15 production tubing suspended therefrom.
4. The assembly of claim 1 wherein the christmas tree further comprises a radial annulus bore and a radial production bore.
5. The assembly of claim 4 wherein the christmas tree further comprises an integral production bore valve.
- 20 6. The assembly of claim 4 wherein the tubing hanger further comprises an annulus access channel extending between the first port in the tubing hanger and an annulus, the annulus being defined between the production tubing and an innermost casing.
7. The assembly of claim 6 further comprising a plurality of annulus access channels arranged about the tubing hanger and extending between the annulus and a plurality of
25 first ports.
8. The assembly of claim 7 wherein the plurality of annulus access channels converge to a common eccentric connector.
9. The assembly of claim 8 wherein the plurality of annulus access channels reduce in number between the eccentric connector and the christmas tree radial annulus bore.
- 30 10. The assembly of claim 7 wherein the plurality of annulus access channels provides an equivalent flow area of at least 1.5 inches.

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11. The assembly of claim 6 wherein the crossover stab further defines the annulus access channel.
12. The assembly of claim 7 wherein the crossover stab further defines the plurality of annulus access channels.
- 5 13. The assembly of claim 1 further comprising a biasing member disposed between the tubing hanger and the sliding valve.
14. The assembly of claim 13 wherein the biasing member biases the sliding valve to the closed position.
15. The assembly of claim 11 wherein the crossover assembly further defines the annulus access channel.
- 10 16. The assembly of claim 12 wherein the crossover assembly further defines the more than one annulus access channel.
17. The assembly of claim 15 wherein the sliding valve facilitates fluid communication between the annulus access channel defined by the crossover assembly and the annulus access channel defined by the crossover stab.
- 15 17. The assembly of claim 15 wherein the christmas tree further defines the annulus access channel.
18. The assembly of claim 4 wherein the crossover assembly further comprises a radial annulus bore and a radial production bore.
- 20 19. The assembly of claim 18 wherein the crossover assembly further comprises an orientation helix facilitating the alignment of the crossover radial annulus bore with the tree radial annulus bore and the crossover radial production bore with the tree radial production bore.
20. The assembly of claim 19 further comprising an extendable/retractable production stab, the production stab being extendable between the tree radial production bore and the crossover radial production bore.
- 25 20a. The assembly of claim 20 wherein both the tree and the crossover assembly are independently retrievable when the production stab is retracted.
21. The assembly of claim 20 further comprising an a production stab mechanism; the mechanism comprising a first shaft, a second shaft operatively connected to the first shaft by a pair of bevel gears, and a threaded connection between production stab and the first shaft.
- 30

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22. The assembly of claim 21 wherein the mechanism further comprises an anti-rotation key to prevent the production stab from rotating with the first shaft.
23. The assembly of claim 19 further comprising an extendable/retractable annulus stab, the annulus stab being extendable between the tree radial annulus bore and the crossover radial annulus bore.
- 5 23a. The assembly of claim 23 wherein both the tree and the crossover assembly are independently retrievable when the annulus stab is retracted.
24. The assembly of claim 20 further comprising an annulus stab mechanism; the mechanism comprising a first shaft, a second shaft operatively connected to the first shaft by a pair of bevel gears, and a threaded connection between annulus stab and the first shaft.
- 10 25. The assembly of claim 21 wherein the mechanism further comprises an anti-rotation key to prevent the annulus stab from rotating with the first shaft.
26. The assembly of claim 4 further comprising a second port in the sliding valve to selectively allow fluid communication of chemicals between the second port in the sliding valve and a second port in the tubing hanger.
- 15 27. The assembly of claim 26 wherein the tubing hanger further comprises a chemical injection channel extending between the second port in the tubing hanger and a production tubing.
28. The assembly of claim 27 further comprising a plurality of chemical injection channels arranged about the tubing hanger and extending between the production tubing and a plurality of second ports.
- 20 29. The assembly of claim 28 wherein the plurality of chemical injection channels converge to a common eccentric connector.
30. The assembly of claim 29 wherein the plurality of chemical injection channels reduce in number between the eccentric connector and a christmas tree chemical channel.
- 25 31. The assembly of claim 28 wherein the plurality of chemical injection channels provides an equivalent flow area of at least 0.375 inches.
32. The assembly of claim 27 wherein the crossover stab further defines the chemical injection channel.
- 30 33. The assembly of claim 28 wherein the crossover stab further defines the plurality of chemical injection channels.

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34. The assembly of claim 32 wherein the crossover assembly further defines the chemical injection channel.
35. The assembly of claim 33 wherein the crossover assembly further defines the one or more chemical injection channels.
- 5 36. The assembly of claim 34 wherein the sliding valve facilitates fluid communication between the chemical injection channel defined by the crossover assembly and the chemical injection channel defined by the crossover stab.
37. The assembly of claim 34 wherein the christmas tree further defines the chemical injection channel.
- 10 38. A subterranean oil or gas well assembly comprising:
- a) A wellhead;
 - b) a christmas tree coupled to the wellhead;
 - c) a single bore tubing hanger landed within the wellhead, the tubing hanger having a production tubing suspended therefrom;
- 15 wherein the single bore tubing hanger further comprises a plurality of first closable ports therein, the first closable ports facilitating fluid communication to an annulus defined by the production tubing and an innermost casing.
39. The assembly of claim 38 wherein the single bore tubing hanger further comprises a plurality of tubing hanger annulus access channels extending from at least one of the plurality of first closable ports to the annulus.
- 20 40. The assembly of claim 39 further comprising a plurality of uphole annulus access channels, wherein the plurality of first closable ports are correspondingly alignable with the uphole annulus access channels to facilitate fluid communication between the uphole annulus access channels and the tubing hanger annulus access channels.
- 25 41. The assembly of claim 40 further comprising a crossover assembly landed within the tree, wherein the uphole annulus access channels extend through aligned radial bores in the crossover assembly and the christmas tree.
- 41a The assembly of claim 41 wherein the uphole annulus access channels extend longitudinally through the christmas tree.
- 30 42. The assembly of claim 41 wherein the crossover assembly further comprises a crossover stab and the plurality of first closable ports further comprises a sliding valve.

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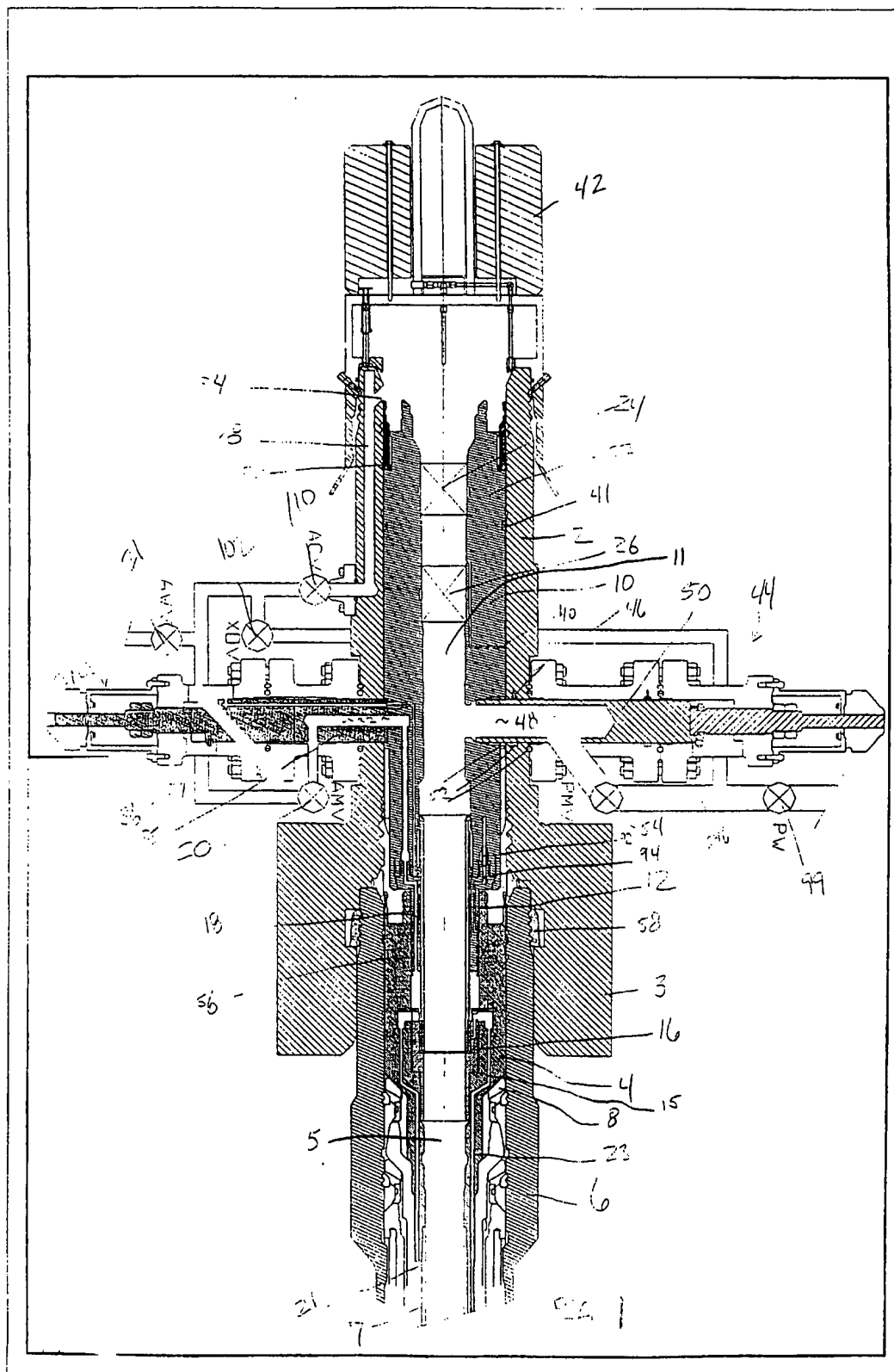
43. The assembly of claim 42 wherein the sliding valve is operable to open and close the first closable ports to selectively allow fluid communication between the tubing hanger annulus access channels and the uphole annulus access channels.
45. The assembly of claim 40 wherein the plurality of uphole annulus access channels
5 converge to a common eccentric connector, and wherein the number of uphole annulus access channels is reduced between the eccentric connector and the christmas tree.
46. The assembly of claim 38 wherein the single bore tubing hanger further comprises a second plurality of closable ports and a plurality of tubing hanger chemical injection channels extending from the second plurality of closable ports, through the tubing hanger,
10 and to the tubing hanger bore.
47. The assembly of claim 46 further comprising a plurality of uphole chemical injection channels, wherein the plurality of first closable ports are correspondingly alignable with the uphole chemical injection channels to facilitate fluid communication between the uphole chemical injection channels and the tubing hanger chemical injection channels.
- 15 48. The assembly of claim 47 further comprising a crossover assembly landed within the tree, wherein the uphole chemical injection channels extend through aligned longitudinal bores [define] arranged about the crossover assembly and the christmas tree.
49. The assembly of claim 48 wherein the crossover assembly further comprises a crossover stab and the plurality of second closable ports further comprises a sliding valve.
- 20 50. The assembly of claim 49 wherein the sliding valve is operable to open and close the second closable ports to selectively allow fluid communication between the tubing hanger chemical injection channels and the uphole chemical injection channels.
51. The assembly of claim 46 wherein the plurality of uphole chemical injection channels converge to a common eccentric connector, and wherein the number of uphole chemical injection channels is reduced between the eccentric connector and the christmas tree.
- 25 52. A method of servicing a subterranean well comprising the steps of:
- a) providing a wellhead
 - b) installing a tubing hanger the wellhead, the tubing hanger comprising:
a bore concentric with the wellhead and a plurality of channels bored
30 longitudinally partially therethrough, the plurality of channels being spaced around the circumference of the tubing hanger;

- 40 -

- c) installing a christmas tree with an internal crossover assembly mounted therein onto the wellhead;
wherein the christmas tree includes an extendable/retractable stab between radial bores in the crossover assembly and christmas tree.

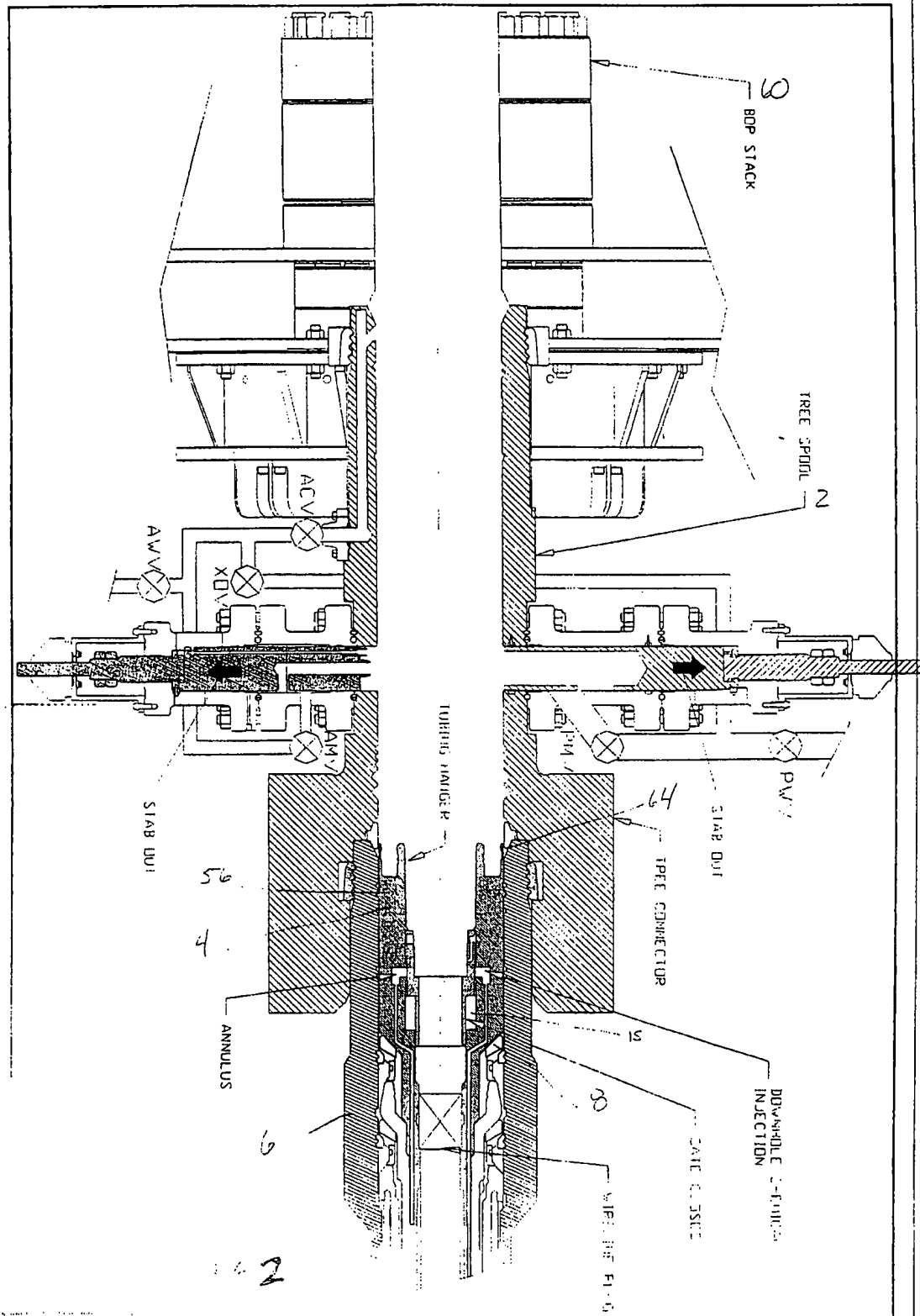
- 5 53. The method of claim 52 further comprising the step of retracting the stab.
54. The method of claim 53 further comprising the step of retrieving the christmas tree separately from the tubing hanger.
55. The method of claim 53 further comprising the step of retrieving the crossover assembly and the tubing hanger while the christmas tree remains connected to the wellhead.
- 10 56. The method of claim 52 wherein the tubing hanger further comprises a plurality of first ports and a plurality of second ports and a sliding valve for selectively opening and closing the first and second pluralities of ports.
57. The method of claim 56 further comprising the step of opening the sliding valve by inserting a crossover stab to position the sliding valve in an open position.

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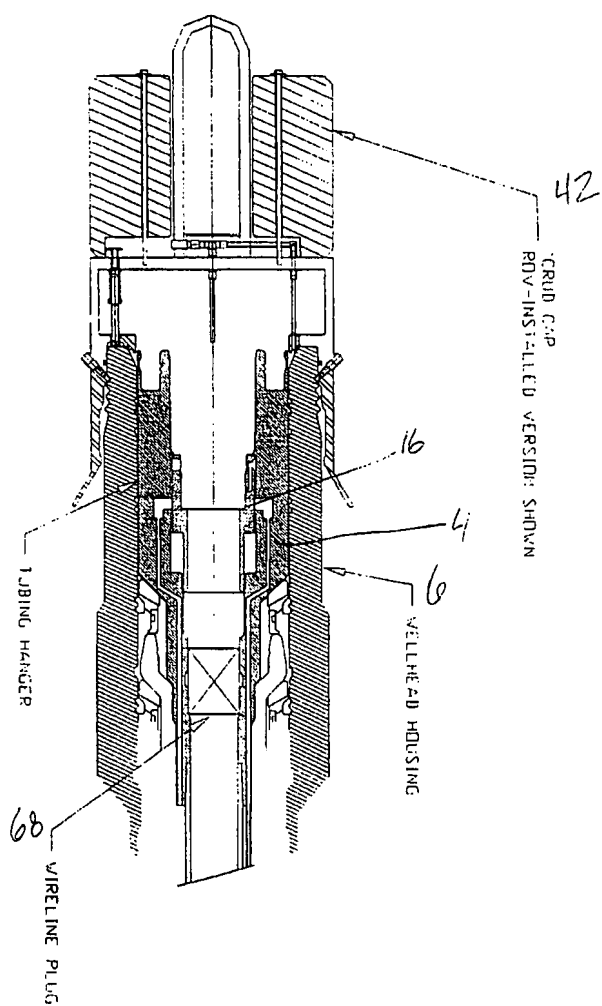
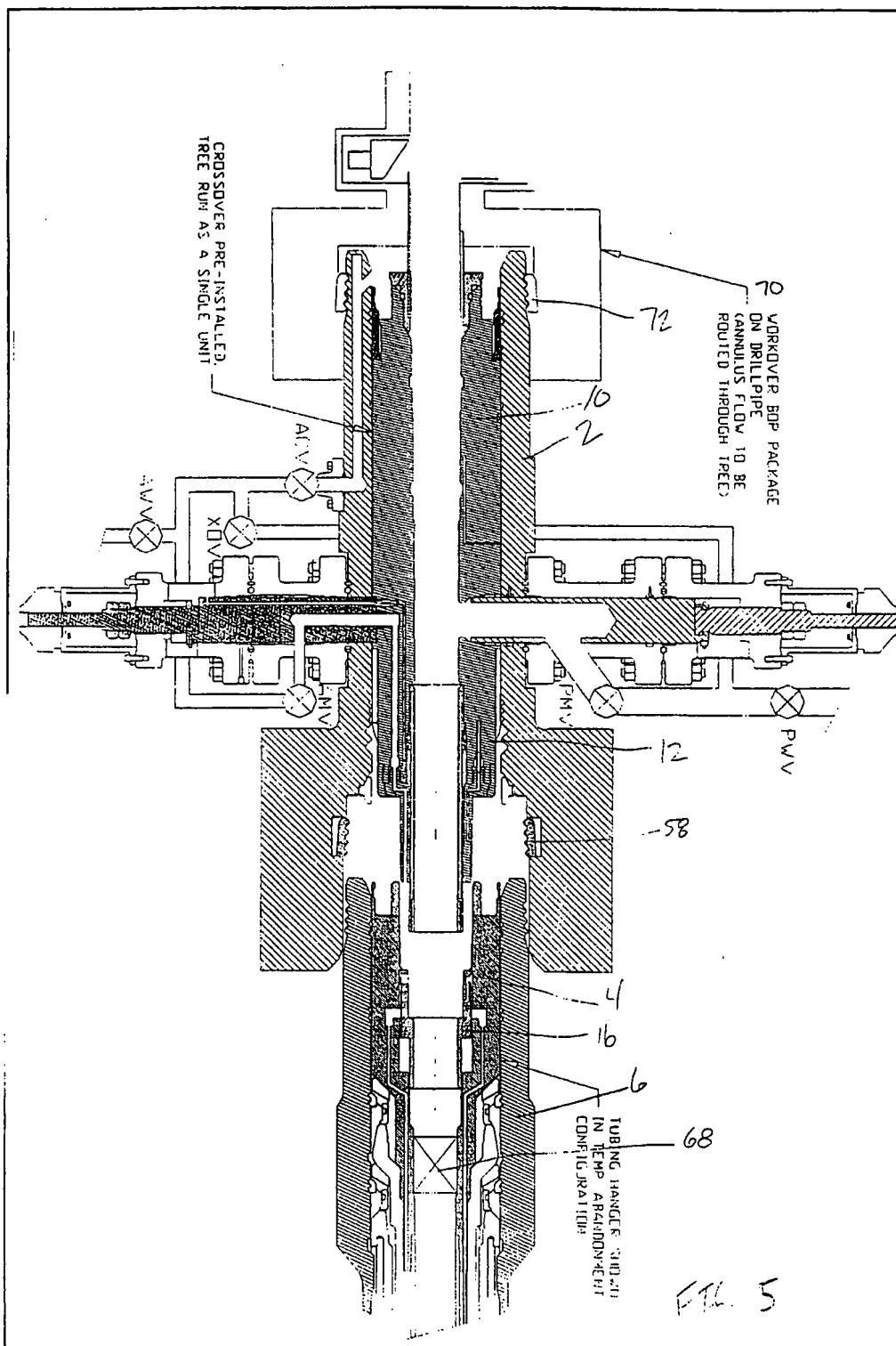
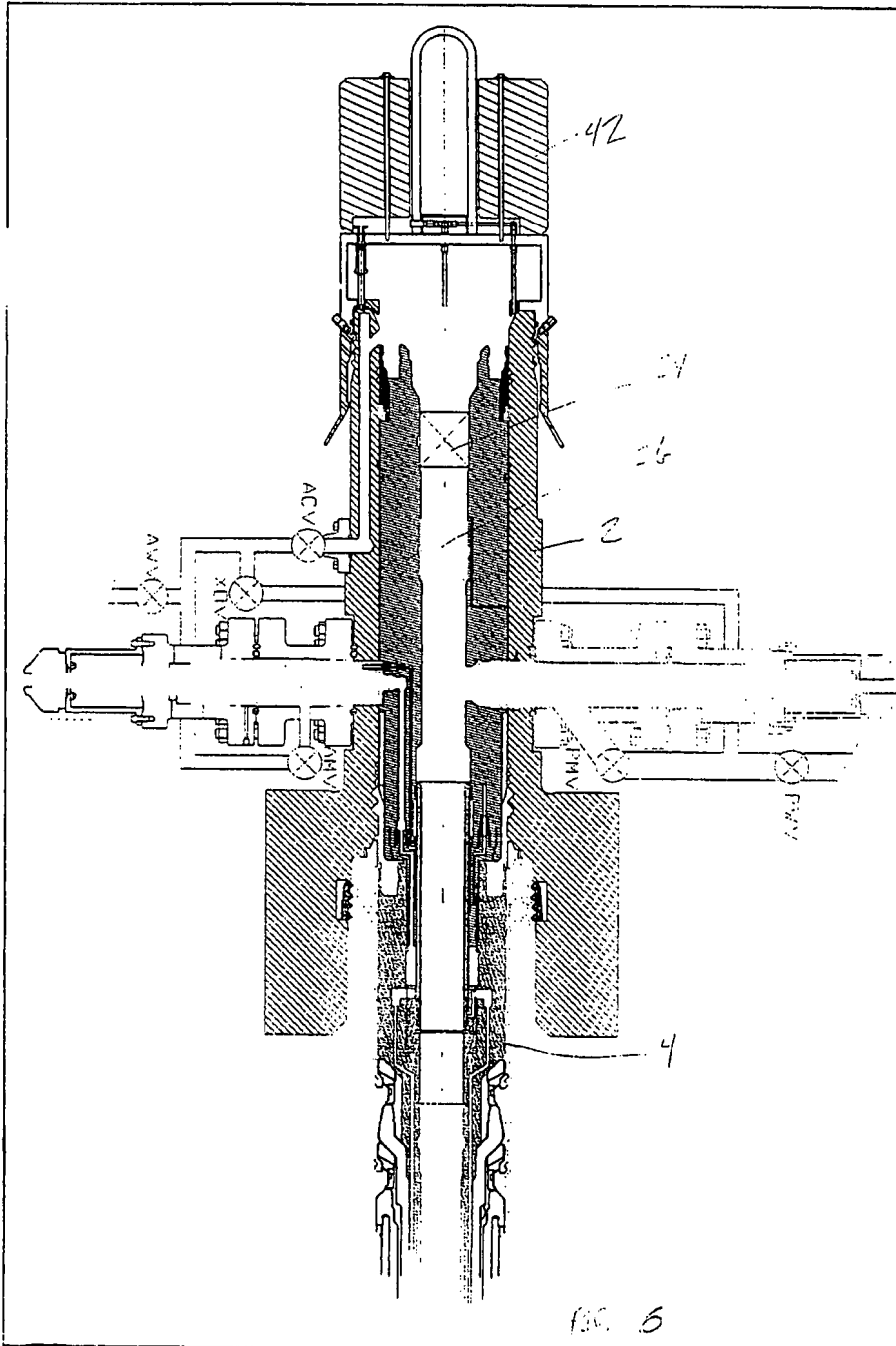


FIG 4

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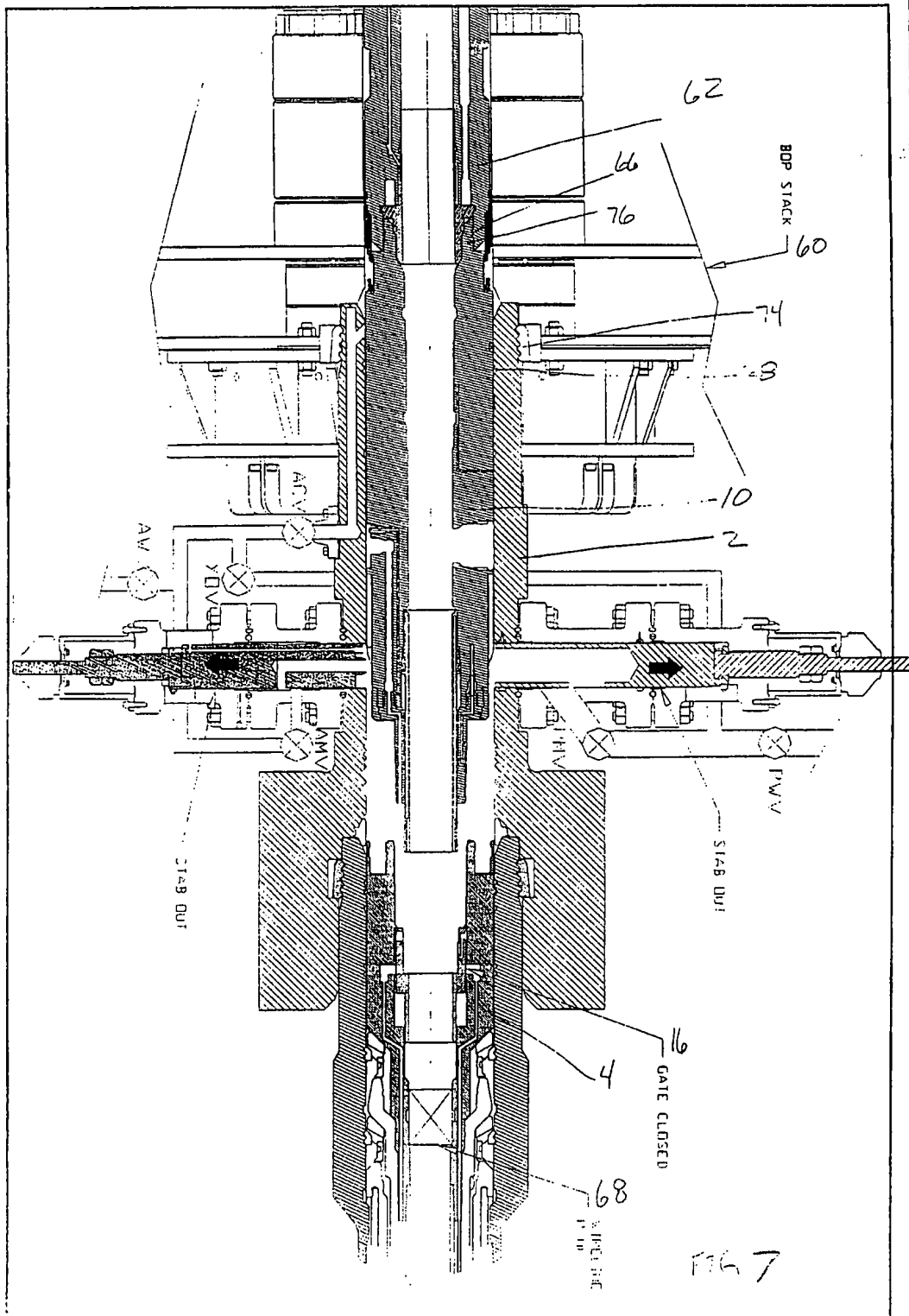


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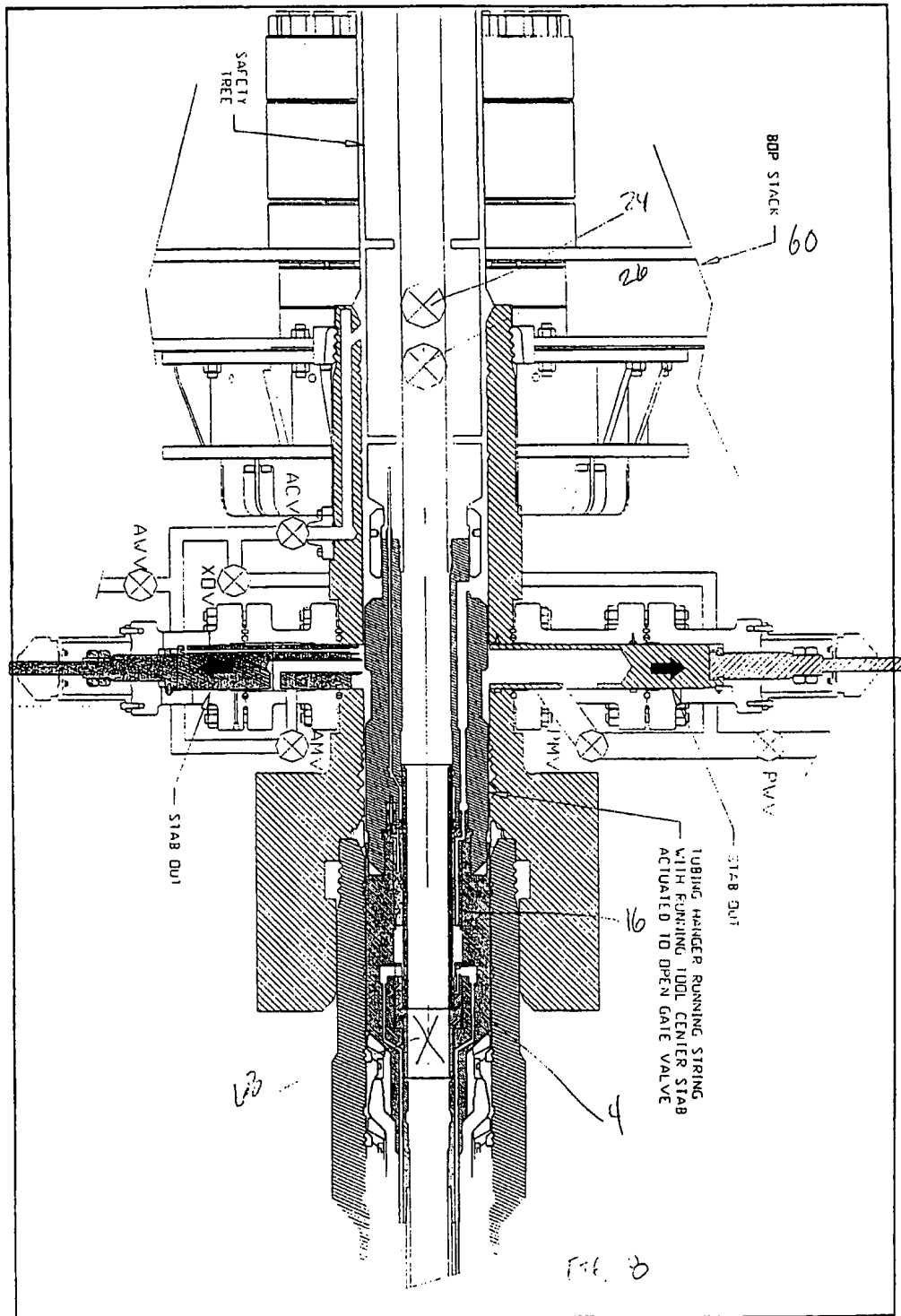
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8



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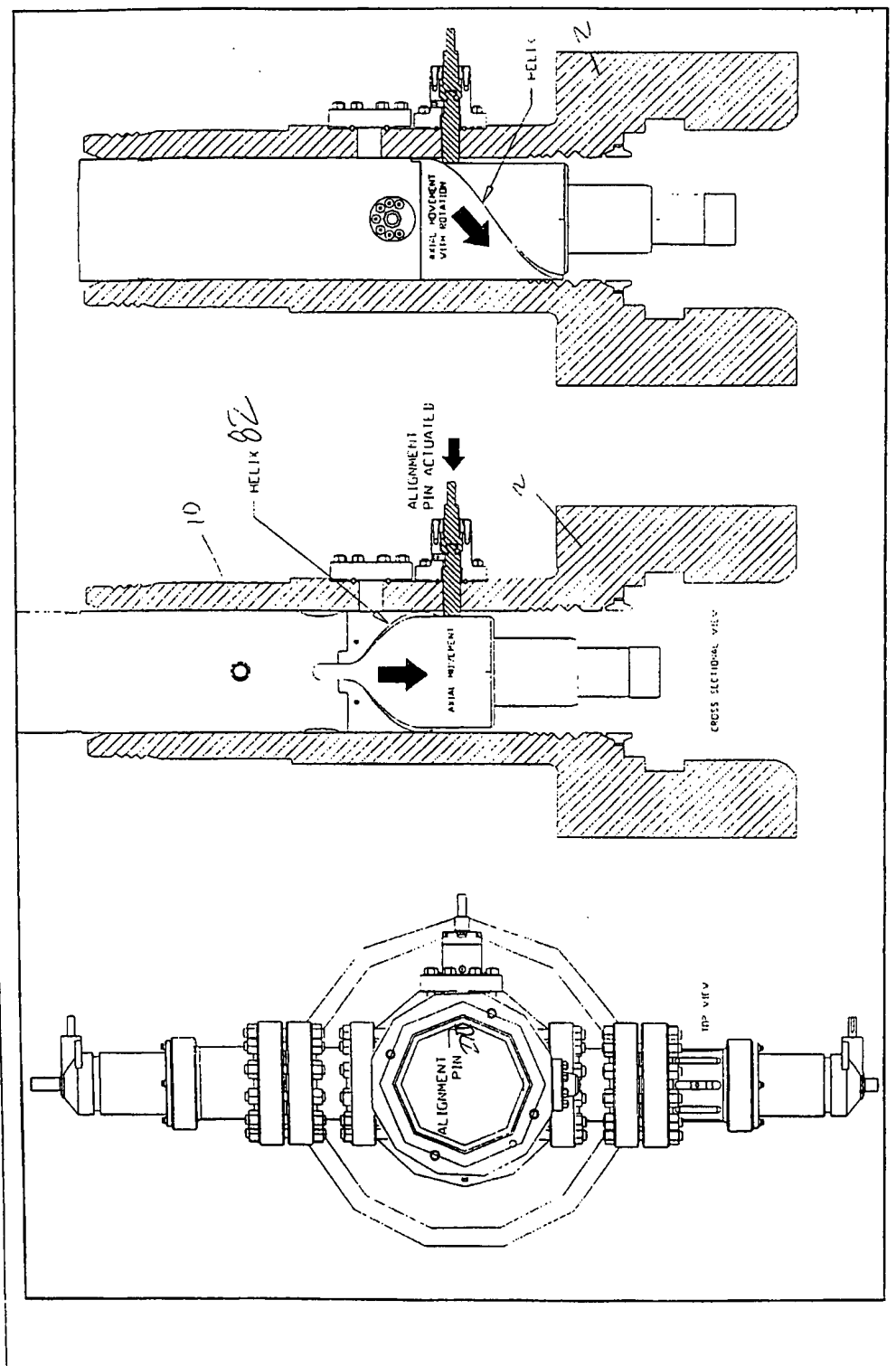


Fig 9c

Fig 9b

Fig 9a

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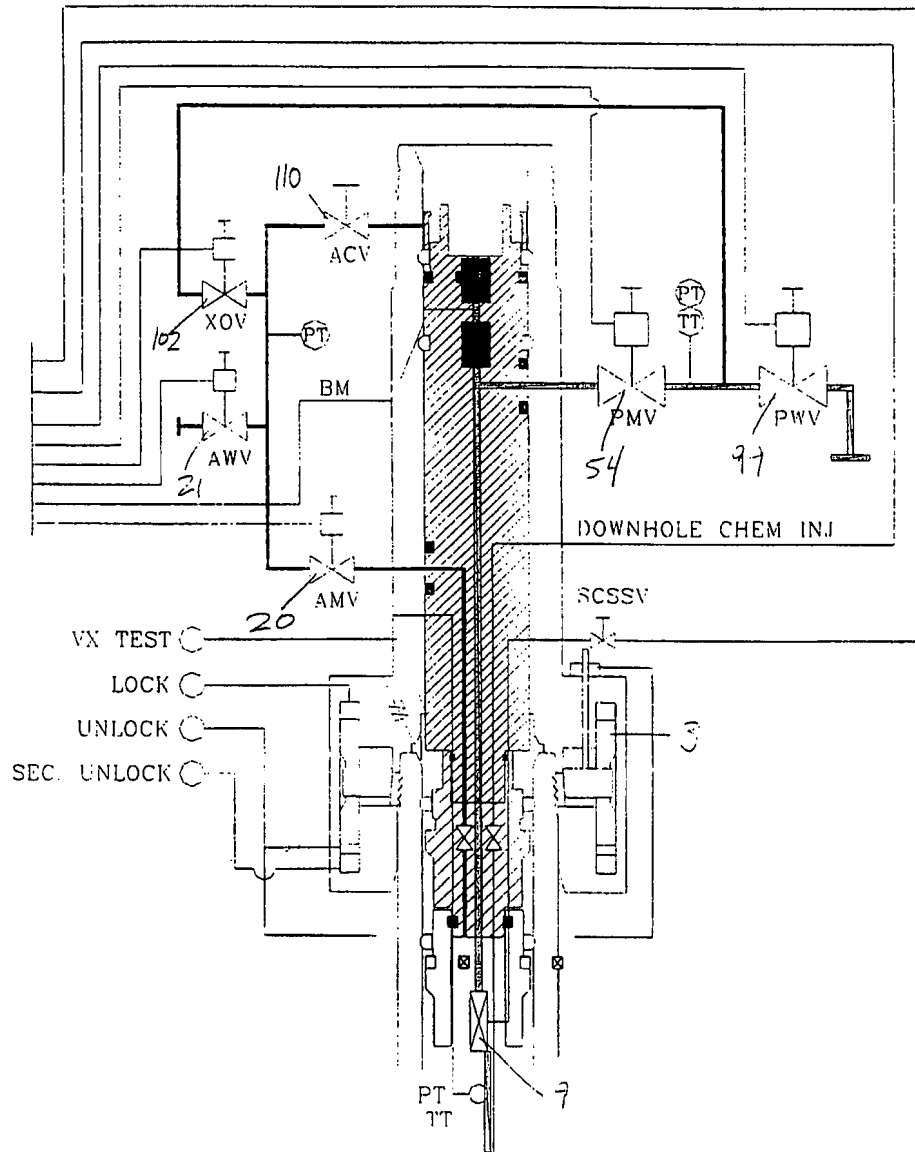


FIG 10

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CTS Subsea Christmas Tree:

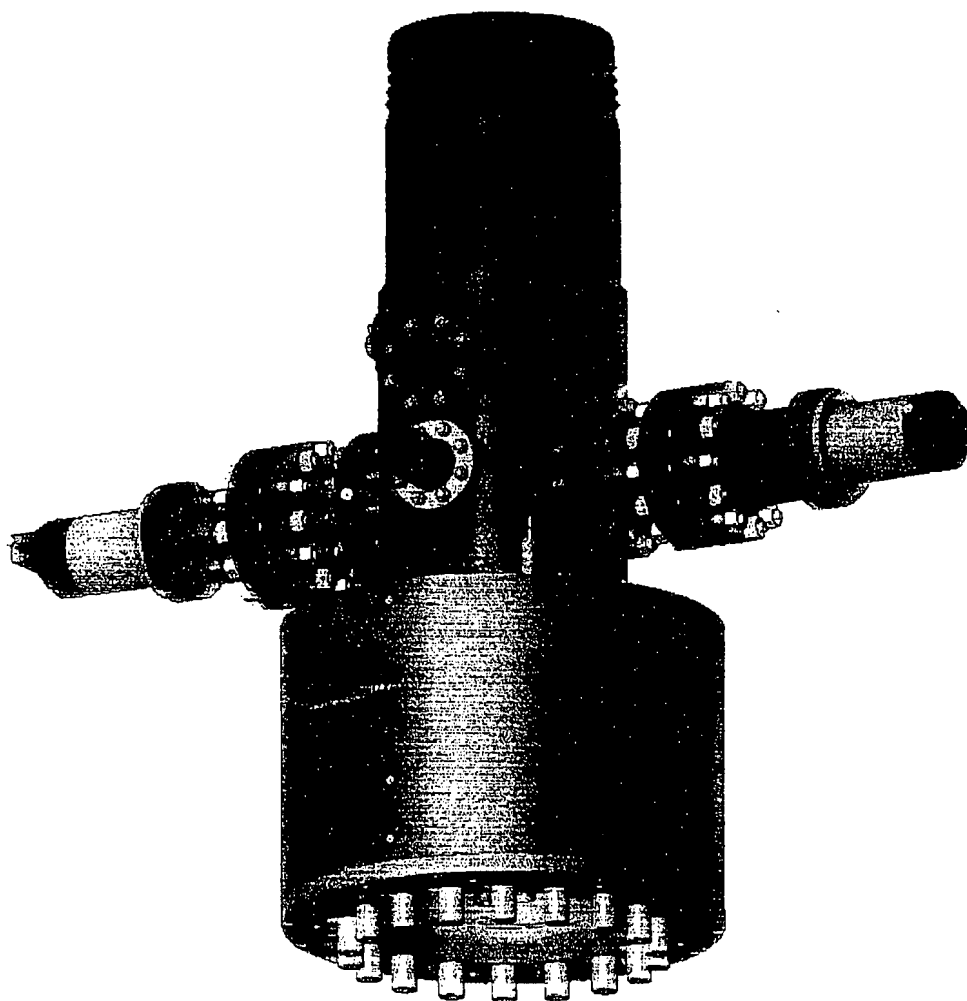


Fig. 1

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CTS Standard Sequence 1,2,3:

- BOP Stack Directly on Wellhead
- Run TH with Multi-Purpose Running Tool (no orientation required)
- Run TH wireline Plug

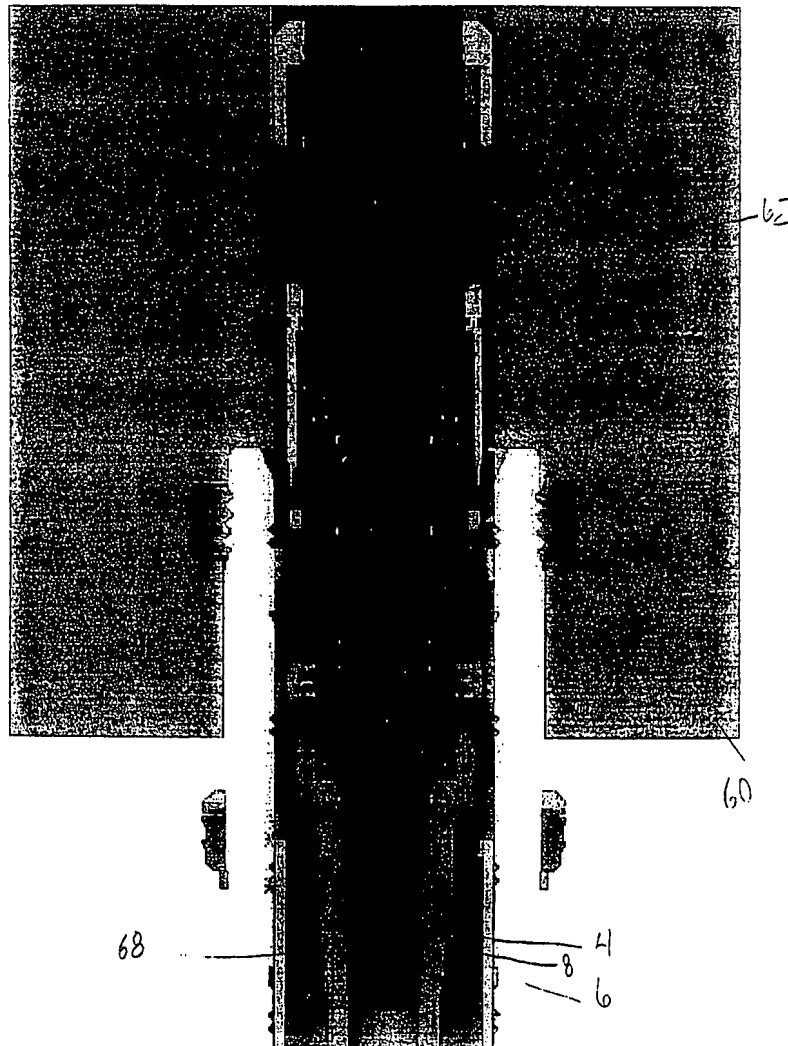


FIG. 1

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CTS Standard Sequence 4:

- Retrieve BOP Stack / ROV Install Debris Cap

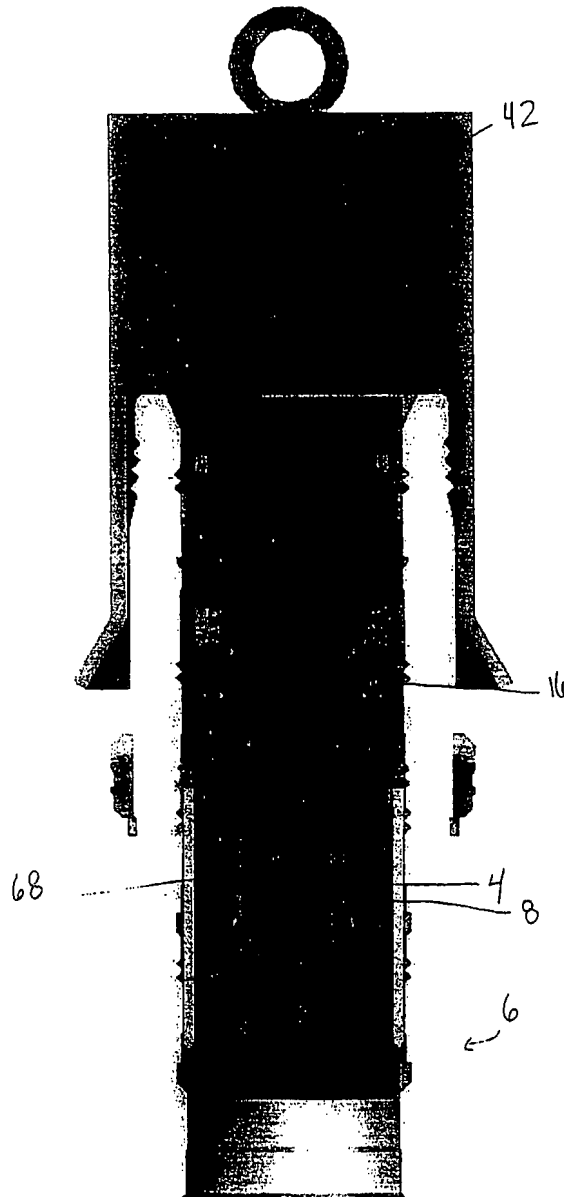
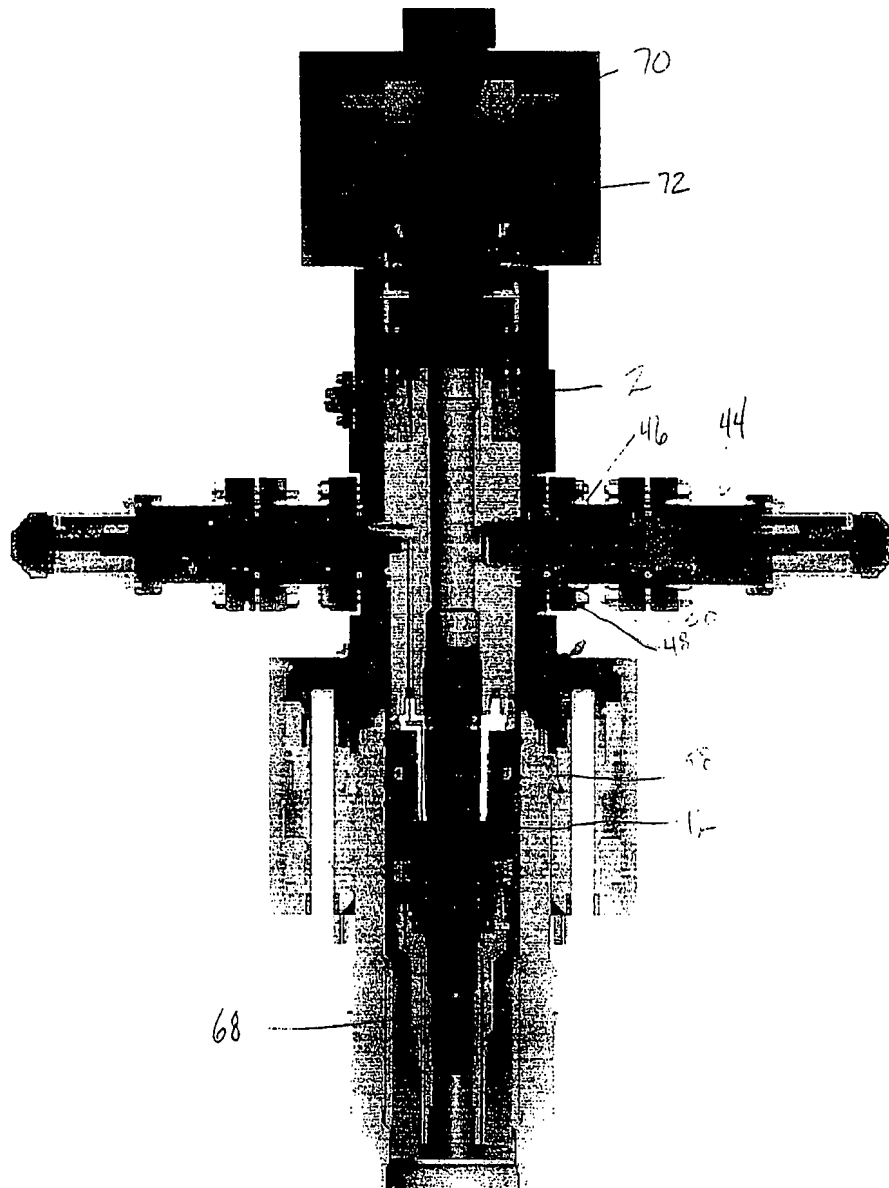


FIG. 13

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CTS Standard Sequence 5:

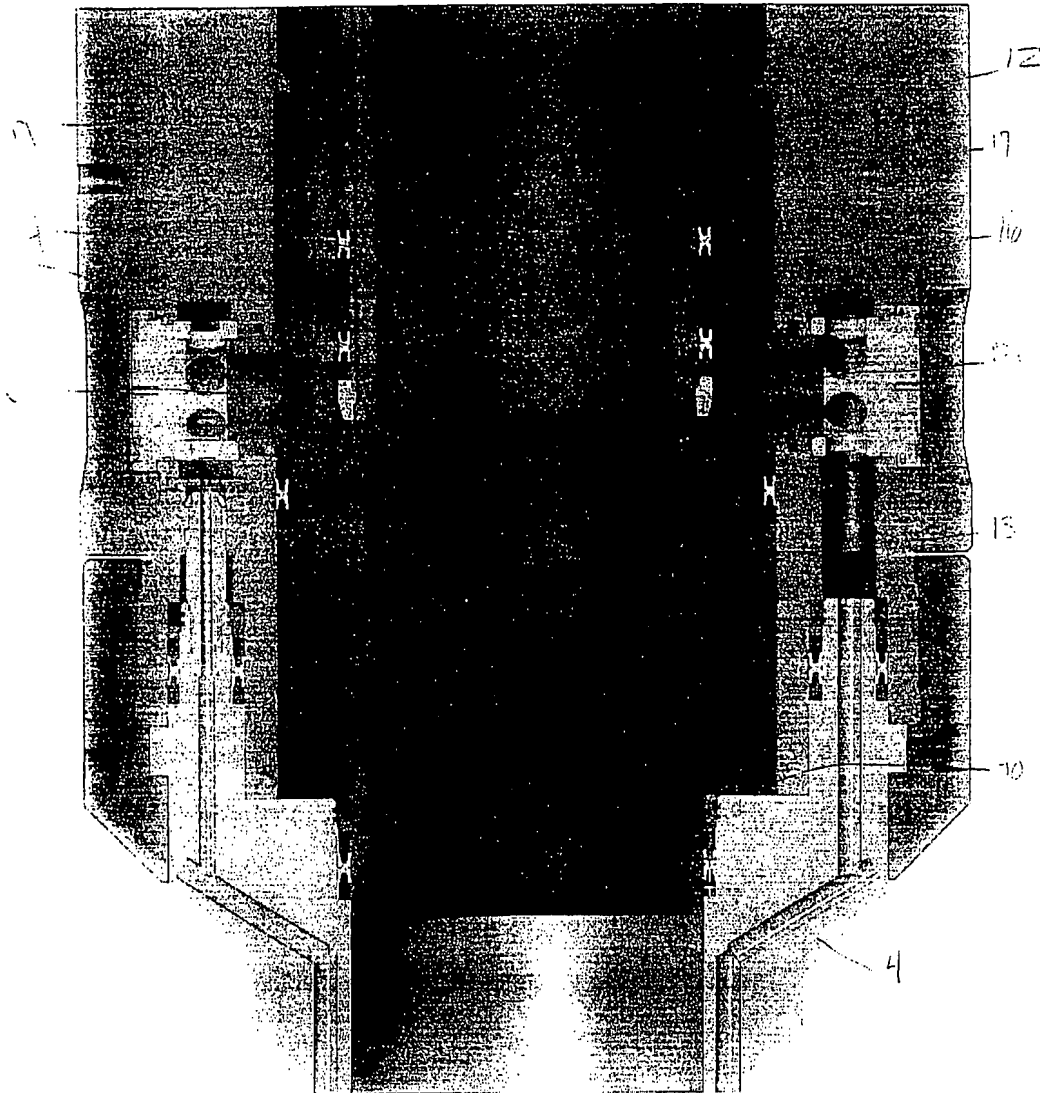
- Run Tree (Crossover Assy Already Installed in Spool Body) with Workover BOP



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CTS Standard Sequence 6a:

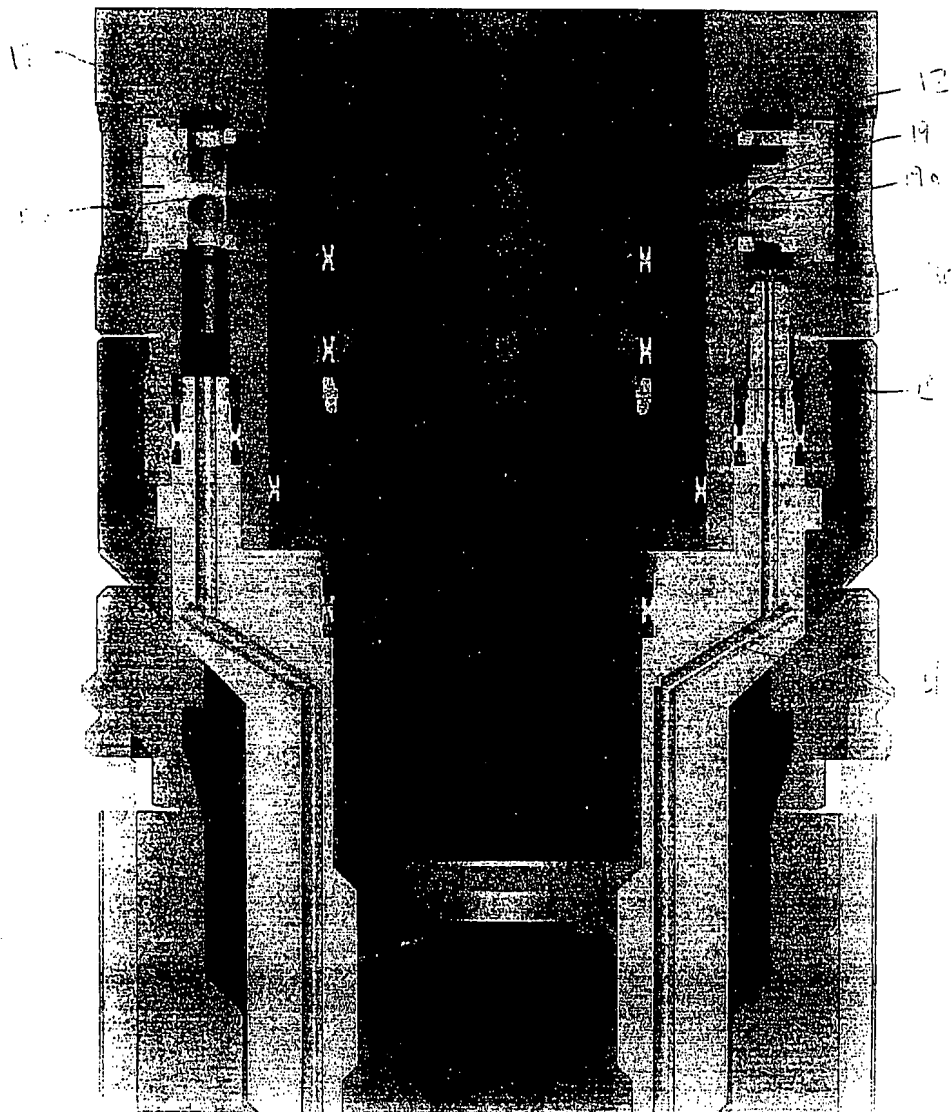
- Crossover Assy Stab enters TH Shuttle Valve



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CT3 Standard Sequence 6b:

- Extend Stab to Open TH Shuttle Valve



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CTS Standard Sequence 7,8,9:

- Retrieve TH Wireline Plug / Install Crossover Wireline Plugs

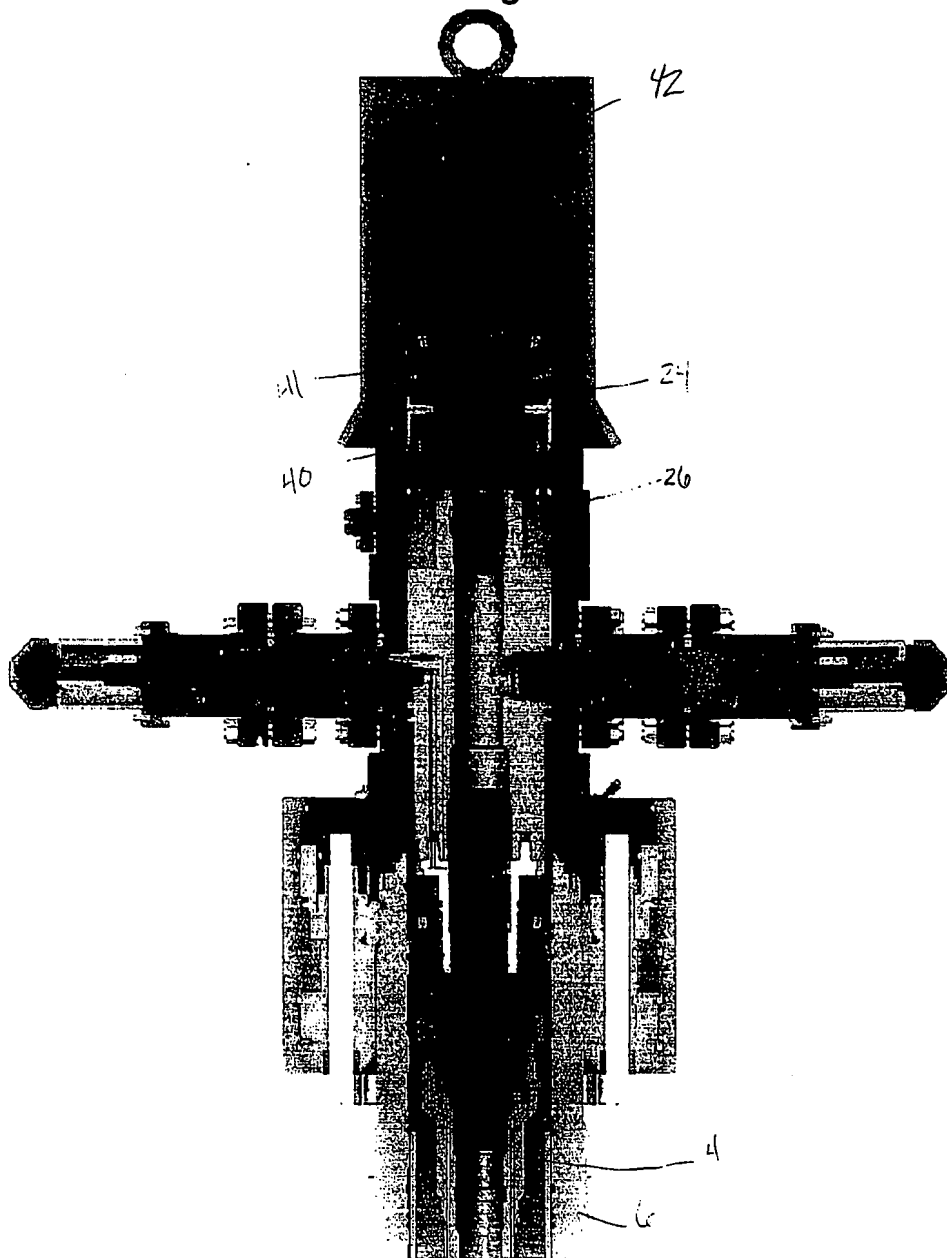
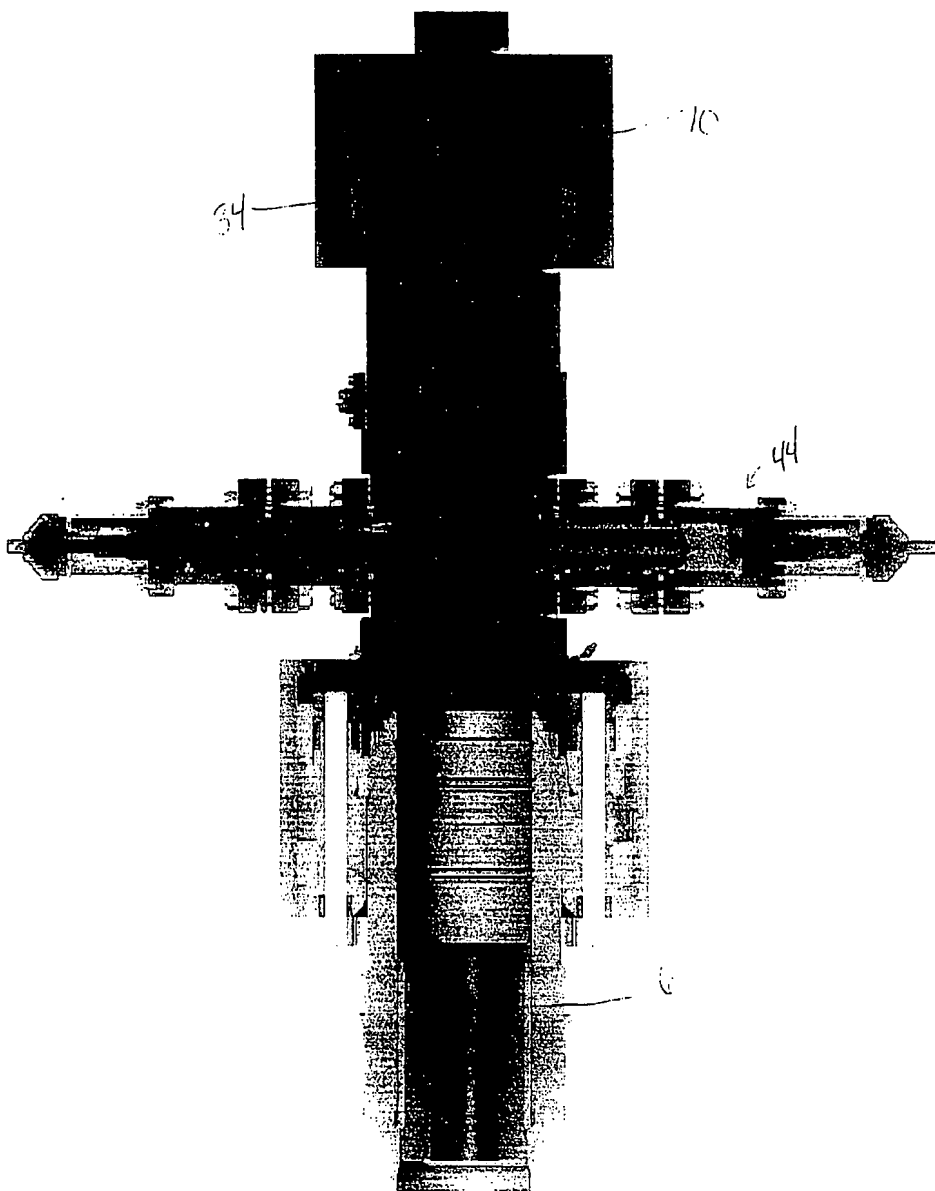


fig. 10

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CTS Optional Sequence 1:

-Lock Empty Spool Body onto Wellhead w/TRT:

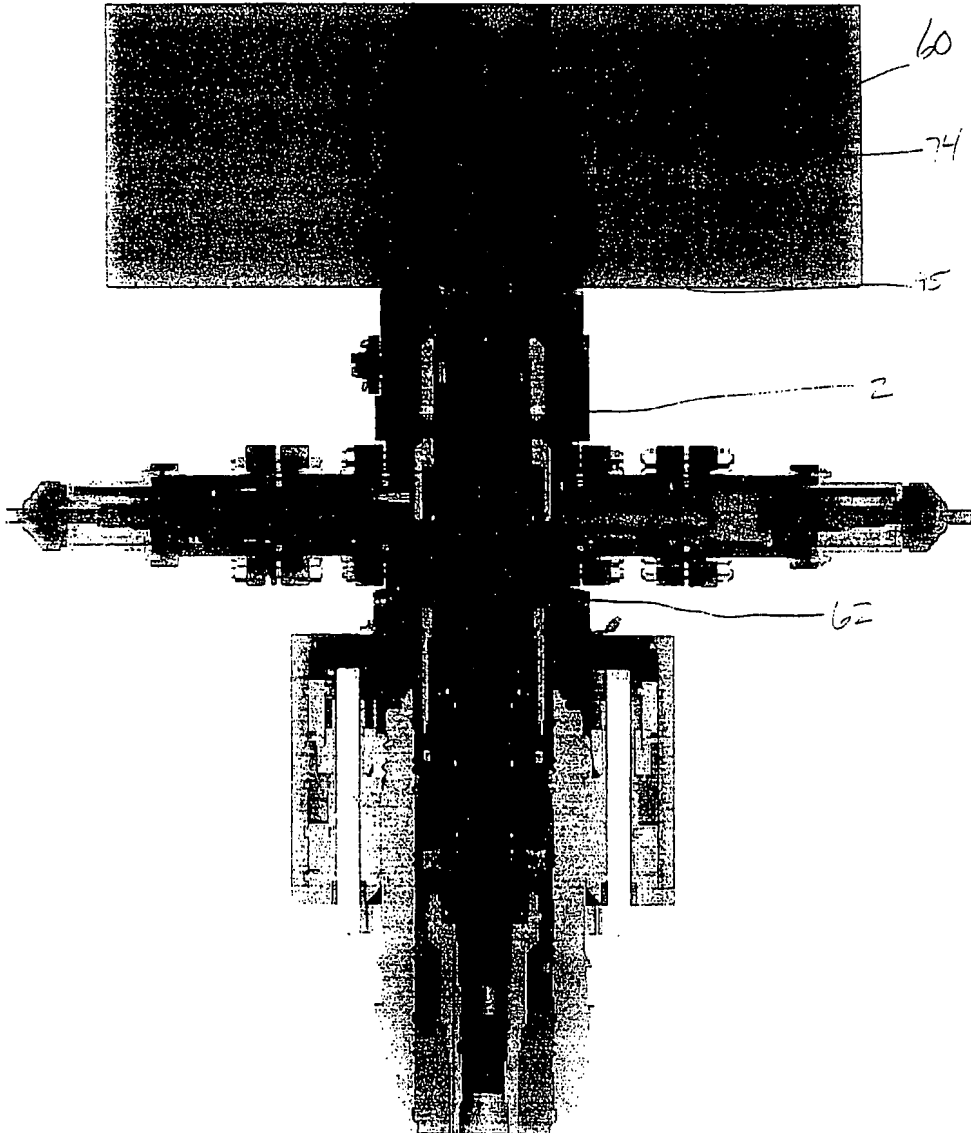


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CTS Optional Sequence 2,3,4:

- Lock BOP Stack Onto Spool Body
- Run TH with Multi-Purpose Running Tool (no orientation required)
- Install TH Wireline Plug



20(39)

CTS Optional Sequence 5:

-Run Crossover Assy with Multi-Purpose Running Tool (self-
orients in Spool Body)

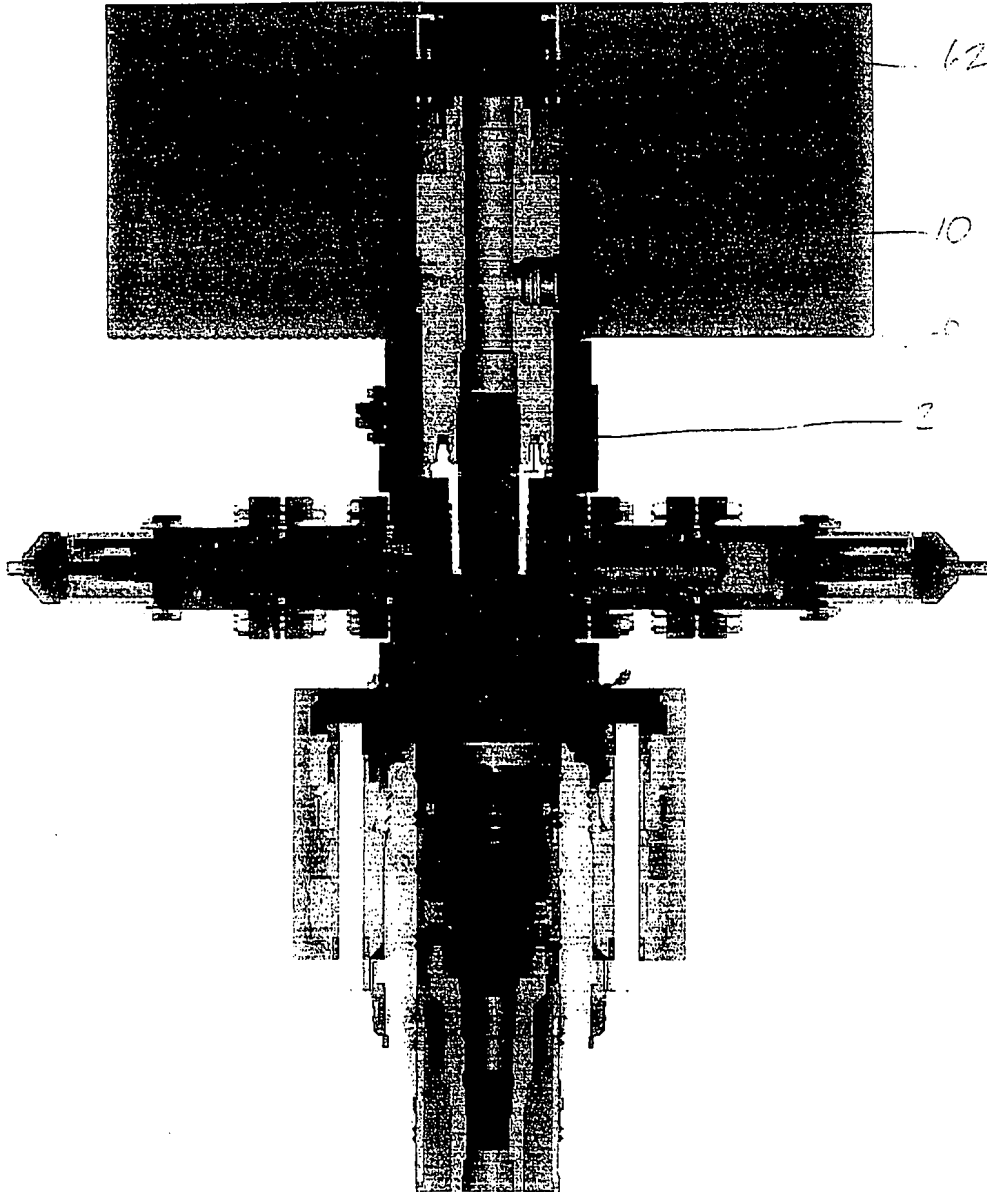


FIG. 19A

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CTS Optional Sequence 5a:

-Detail of Multi-Purpose Running Tool on Crossover Assy

-Note: Stab Replaced by Bore Protector in this Config.

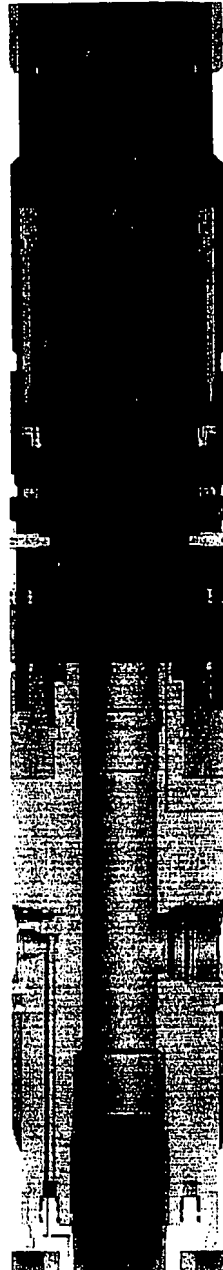
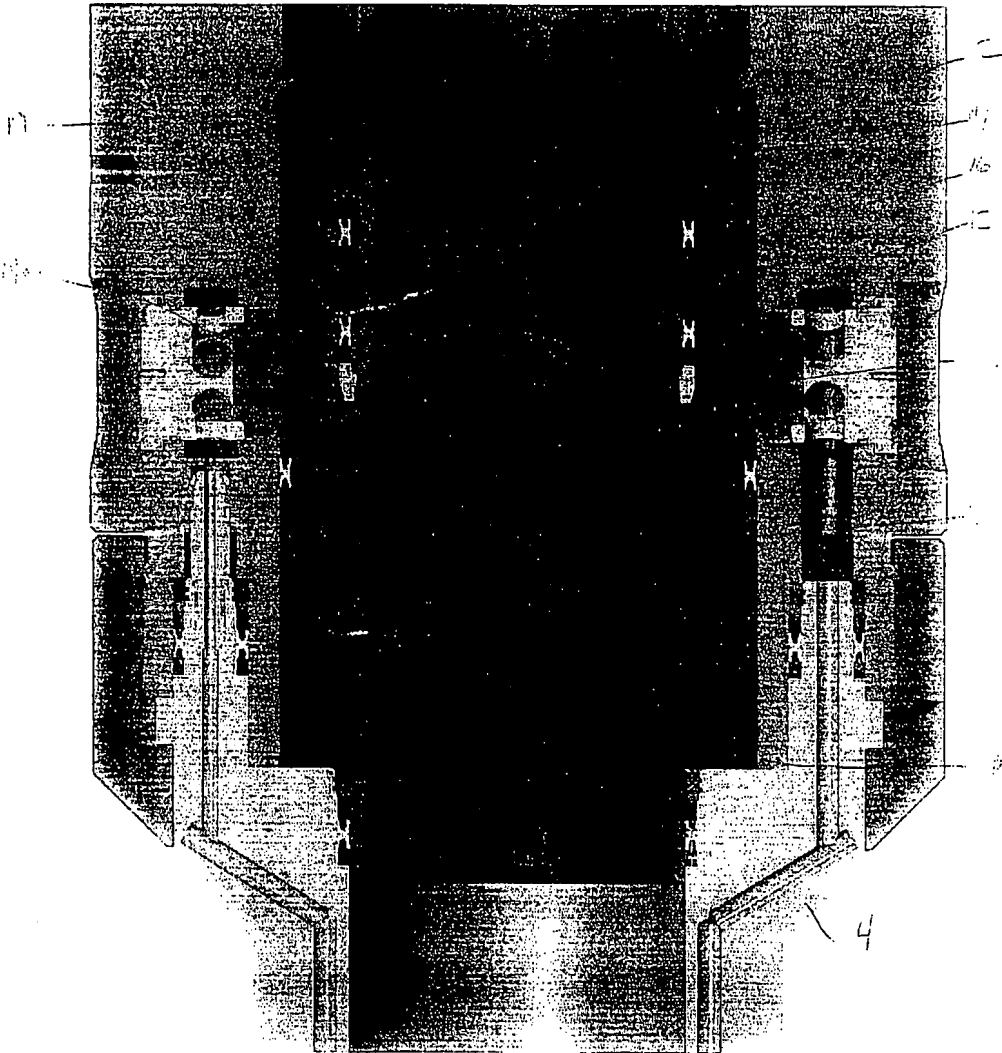


Fig. 19B

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CTS Optional Sequence 6a:

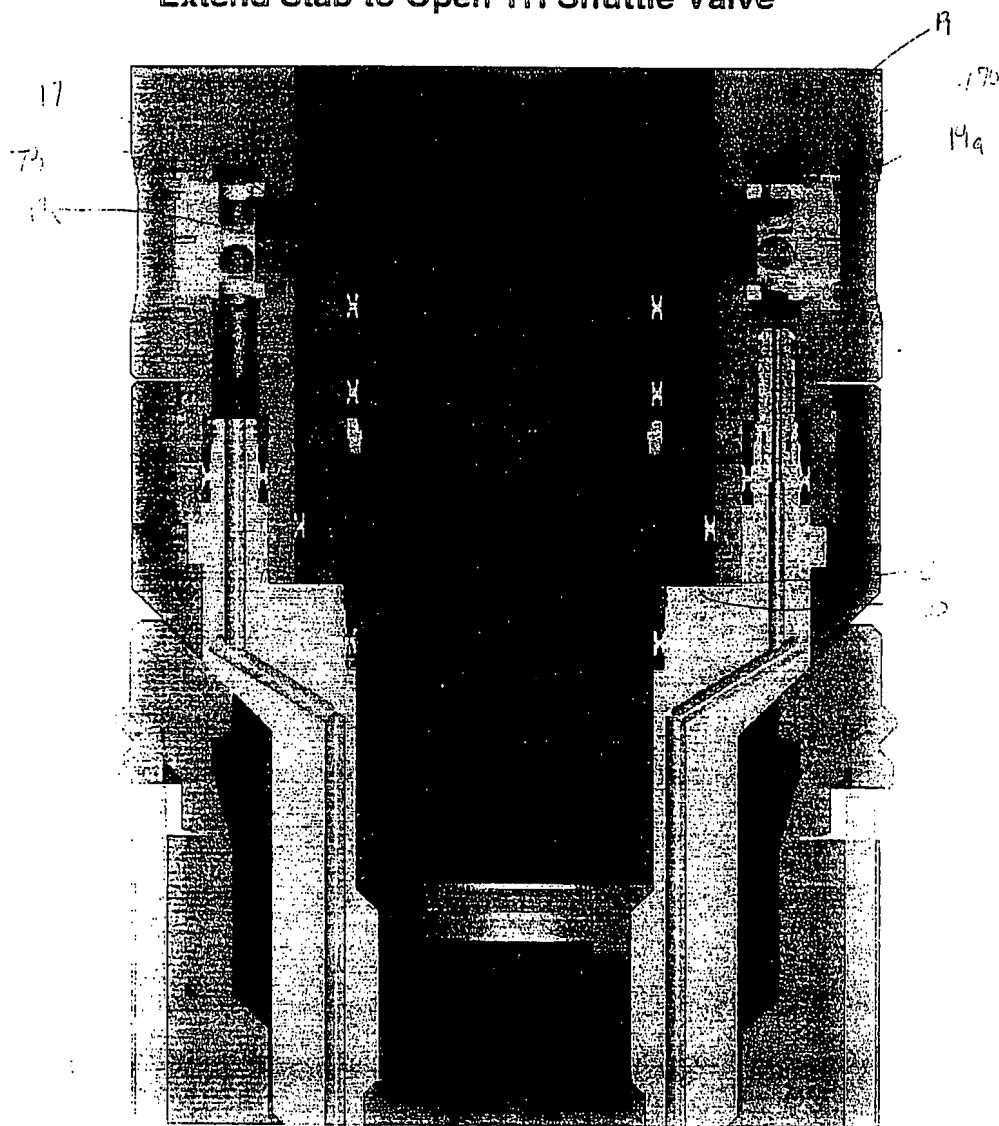
- Crossover Assy Stab enters TH Shuttle Valve



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CTS Optional Sequence 6b:

-Extend Stab to Open TH Shuttle Valve



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CTS Optional Sequence 7,8,9:

–Retrieve TH Plug,

Install Crossover Plugs

–Retrieve BOP Stack

–ROV Install Debris Cap

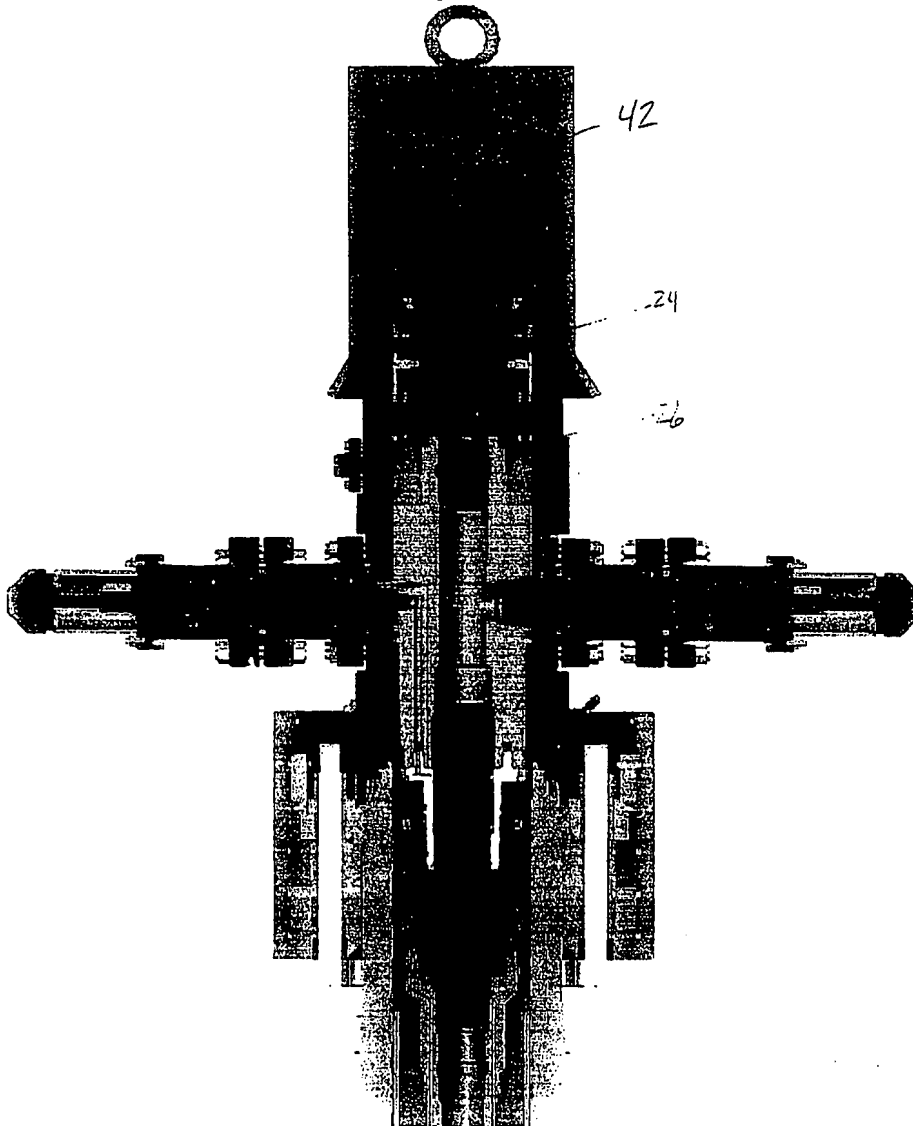
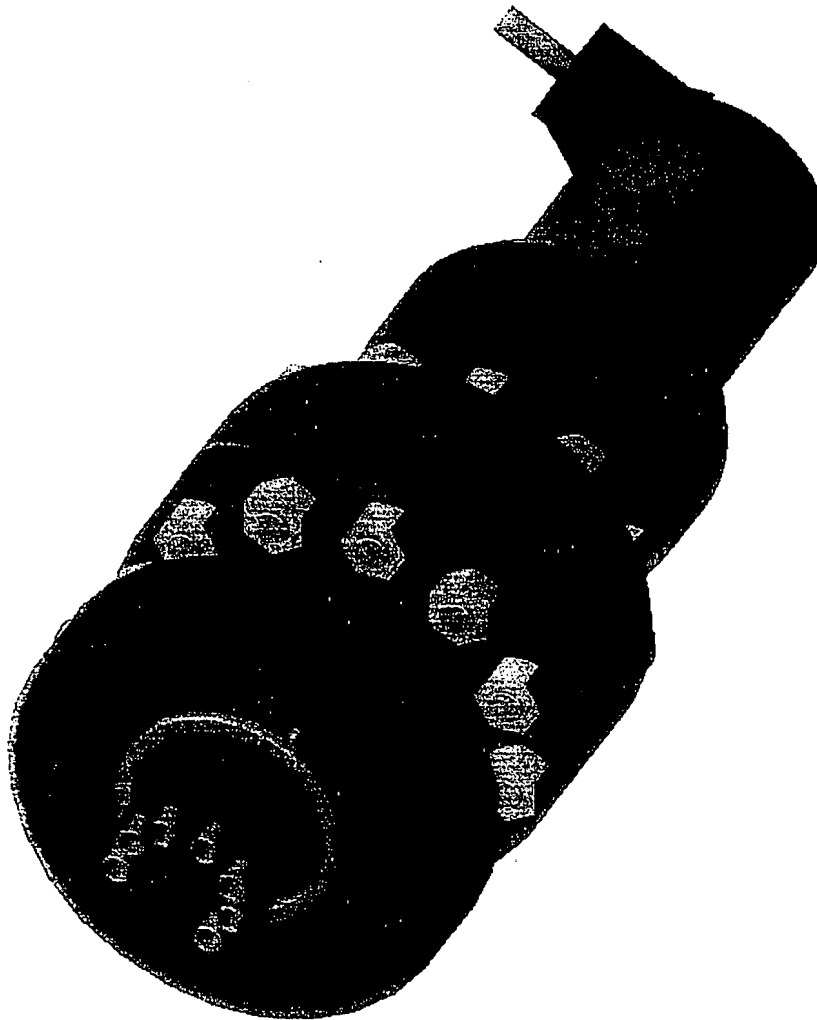


FIG 21

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CTS Combination Stab Detail:

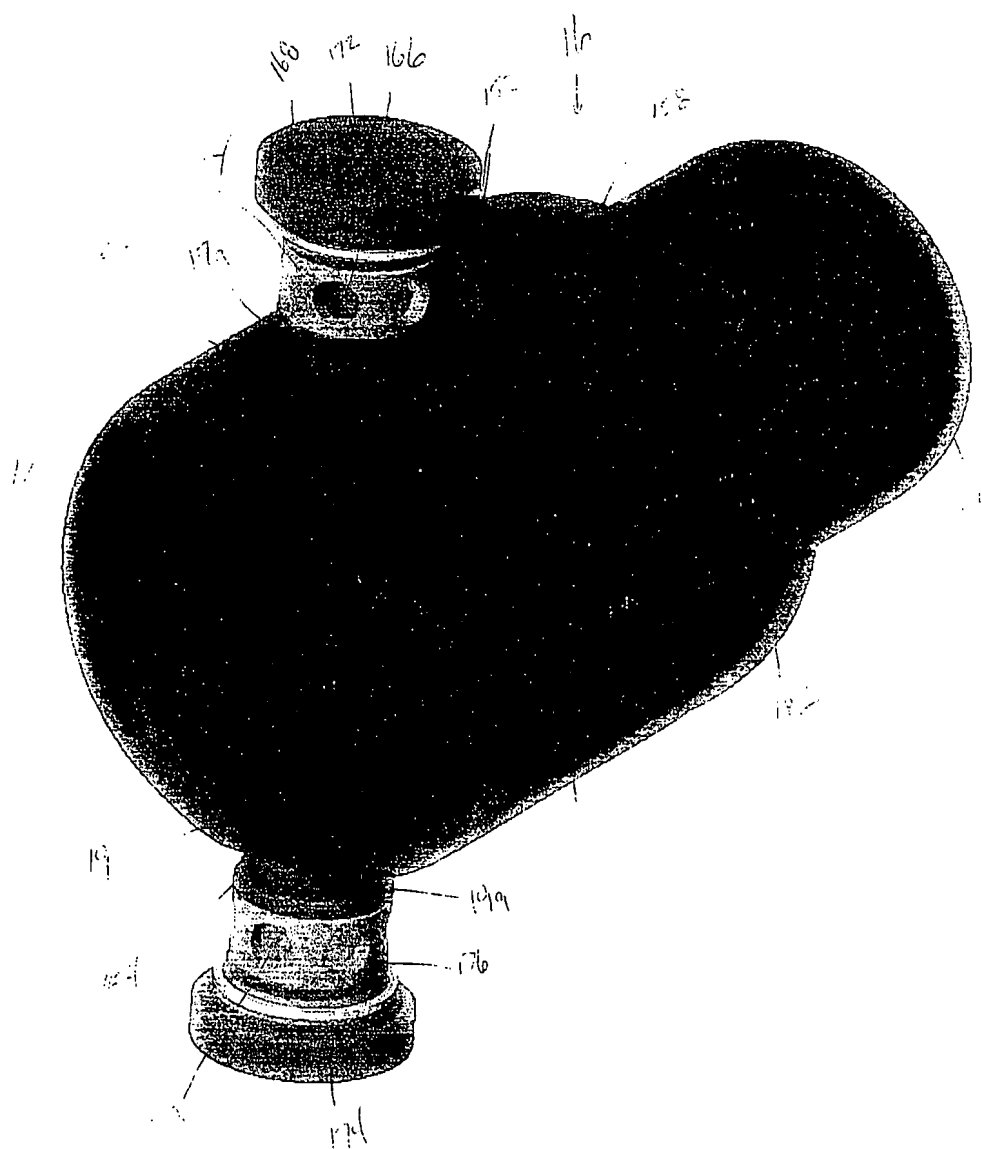


- 2 DHSVs,
- 1 Chem Inj.,
- 1 Stab Down (Function in Crossover),
- 1 Stab Up (Function in TH),
- 1 Elec.

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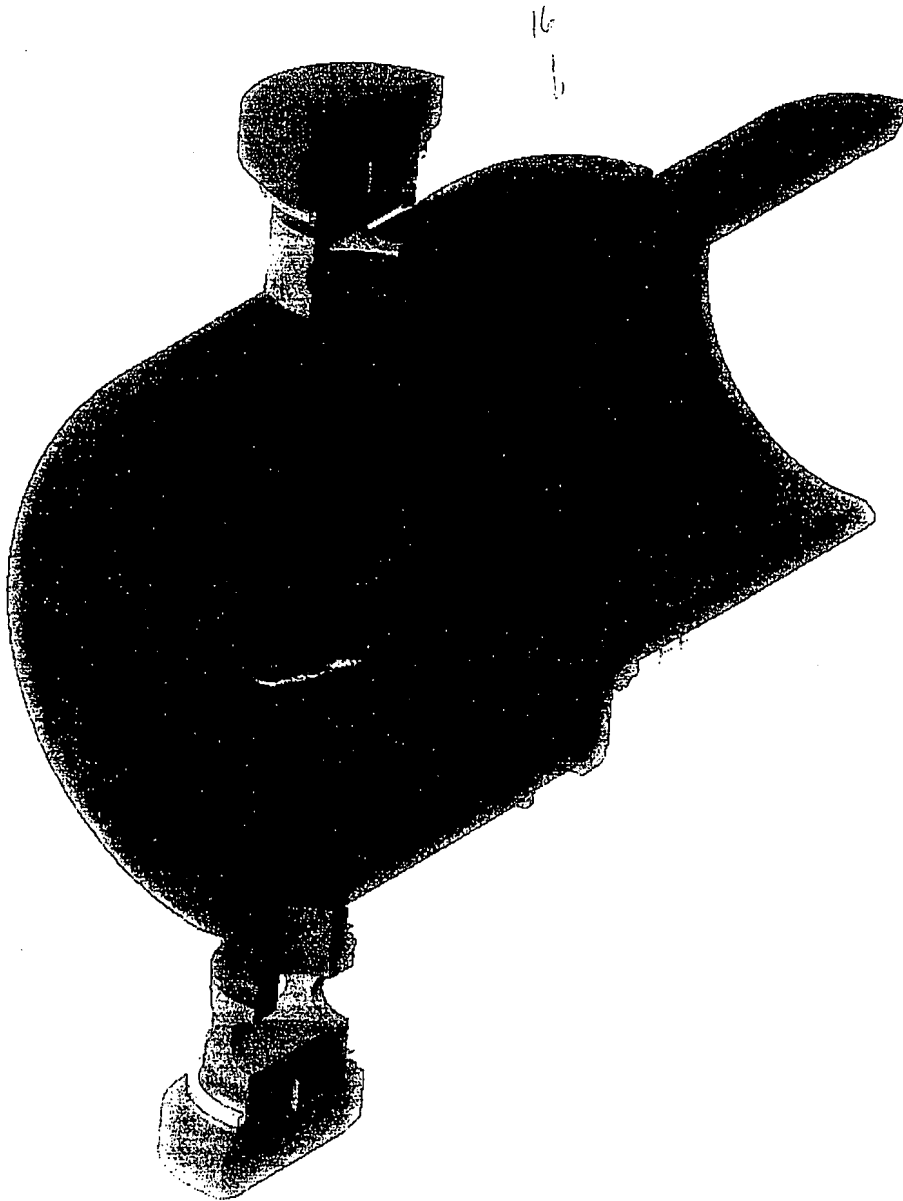
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CTS TH Shuttle Valve Detail.

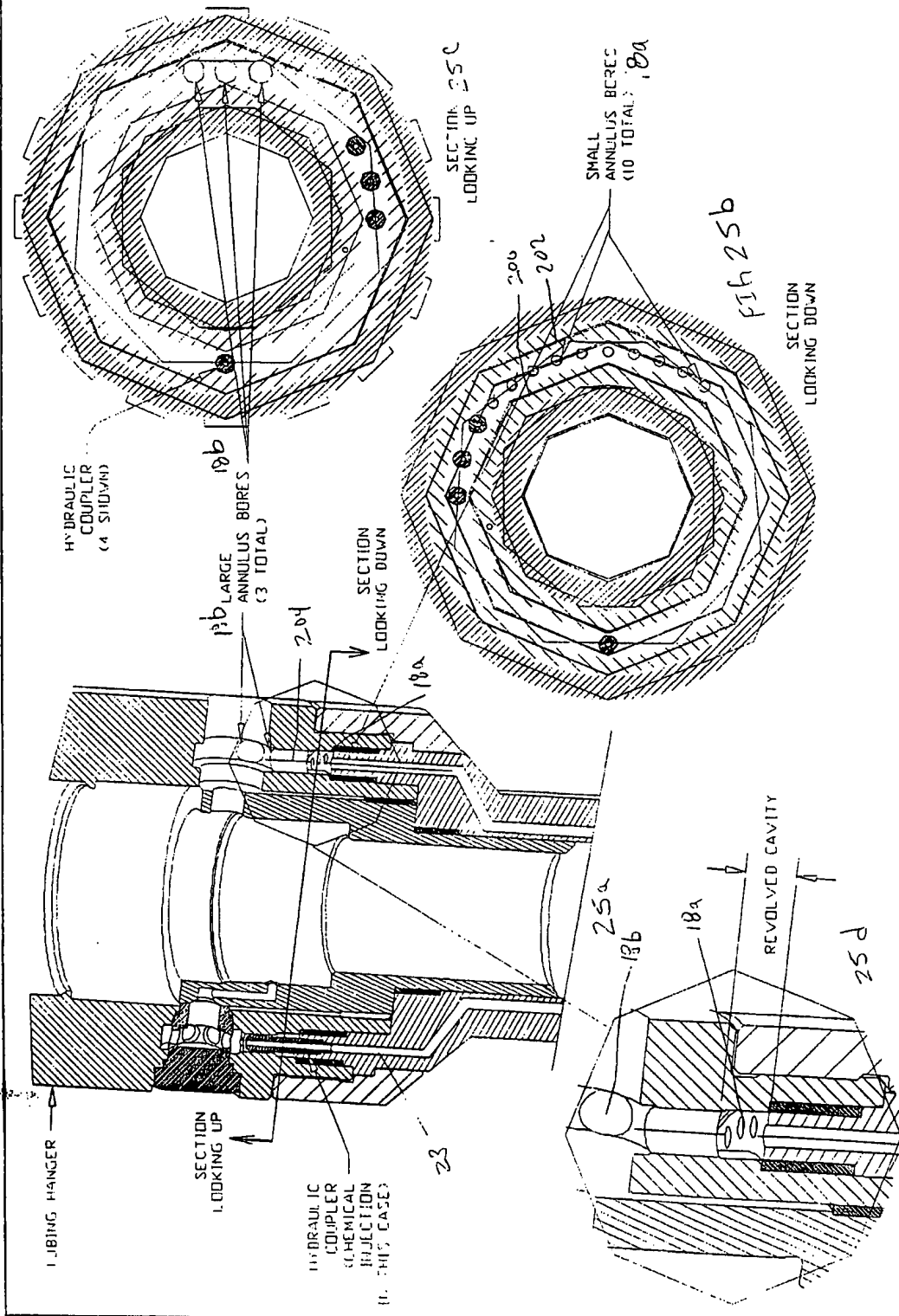


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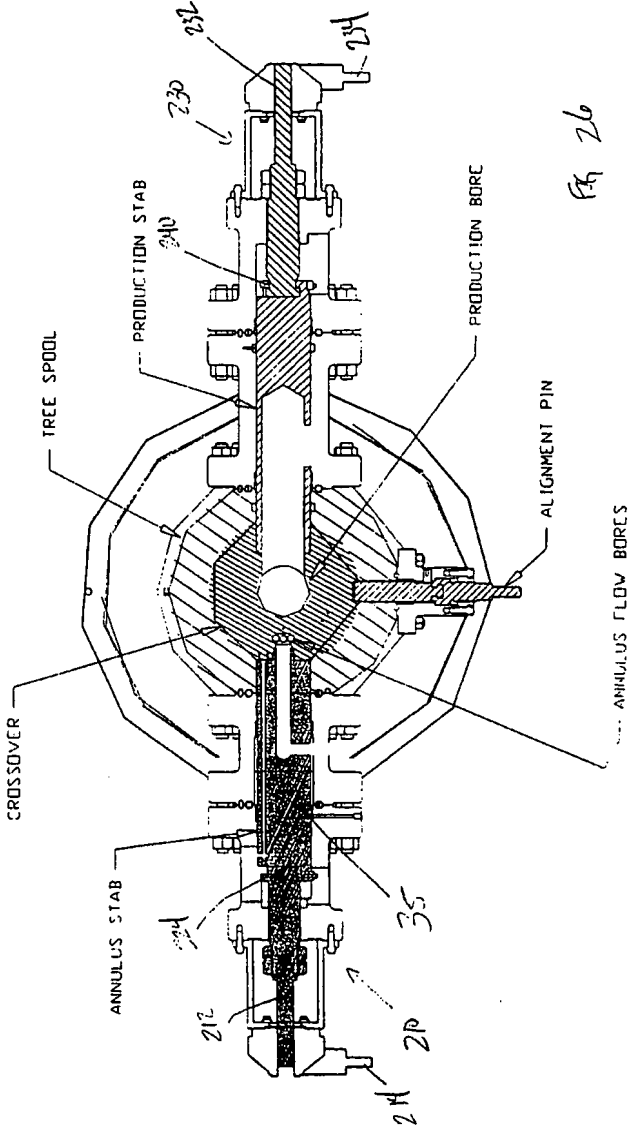
CPS TH Shuttle Valve Internal Detail:



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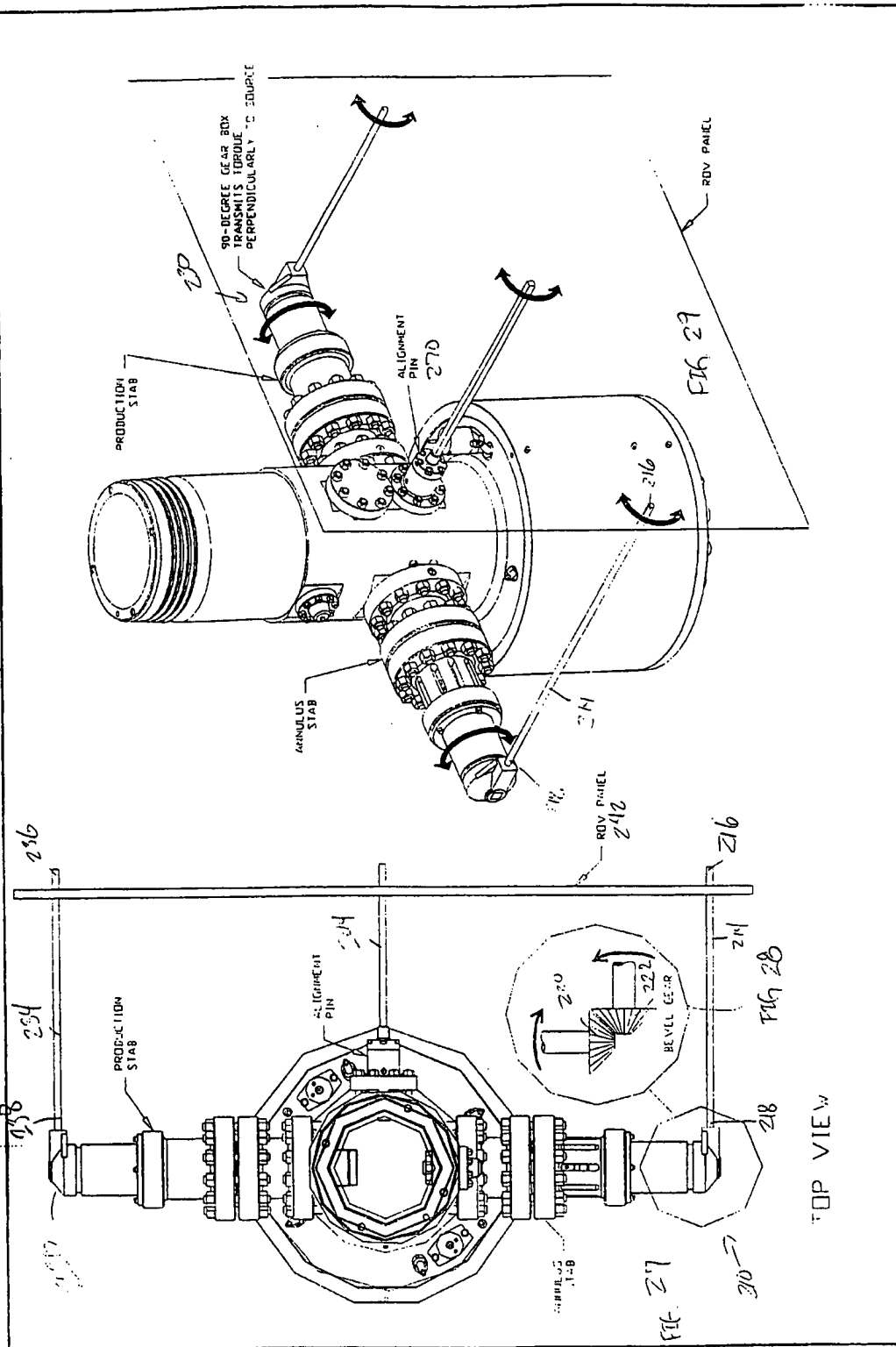


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CROSS SECTIONAL VIEW, LOOKING DOWN

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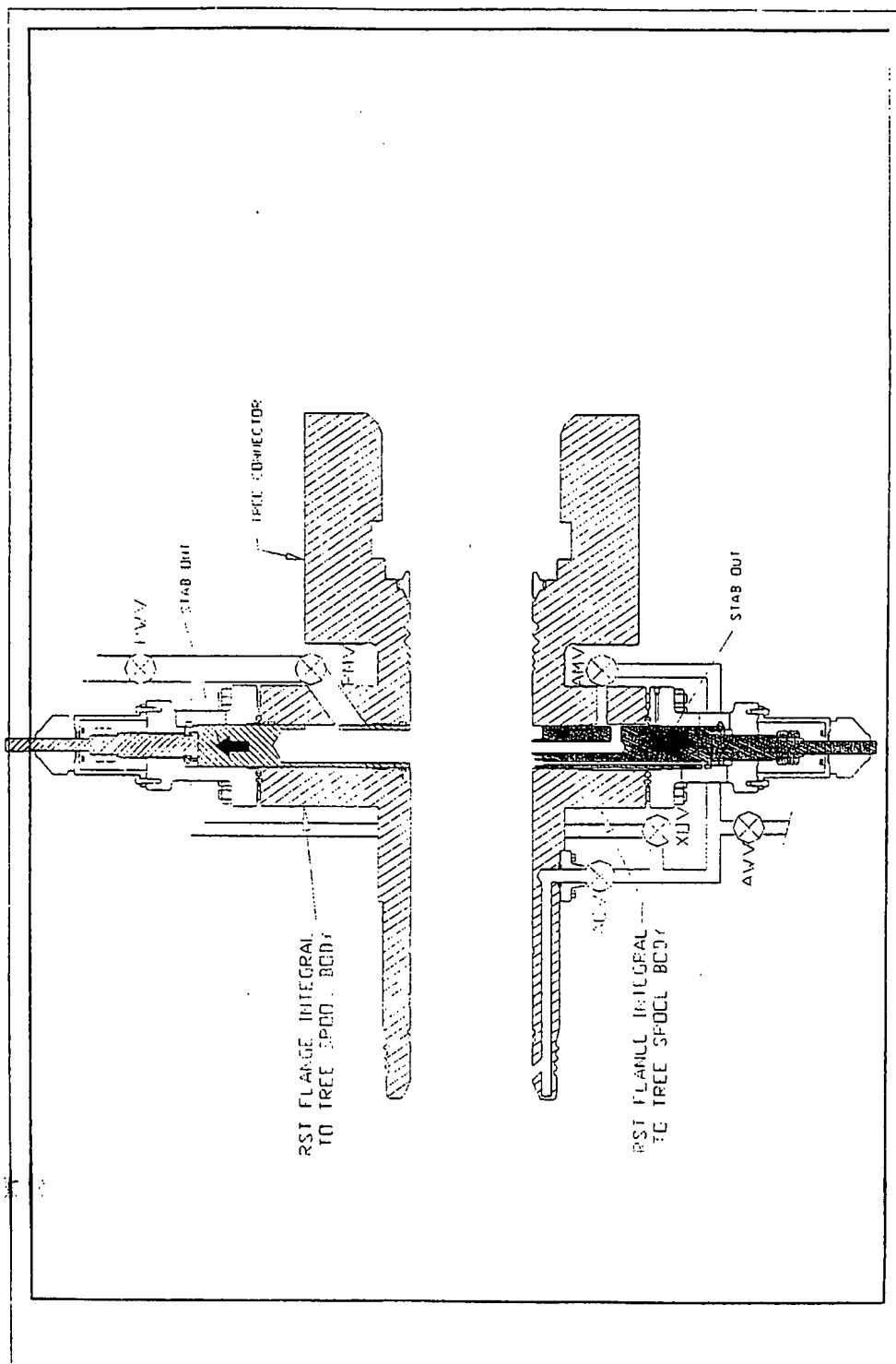


FIG. 30

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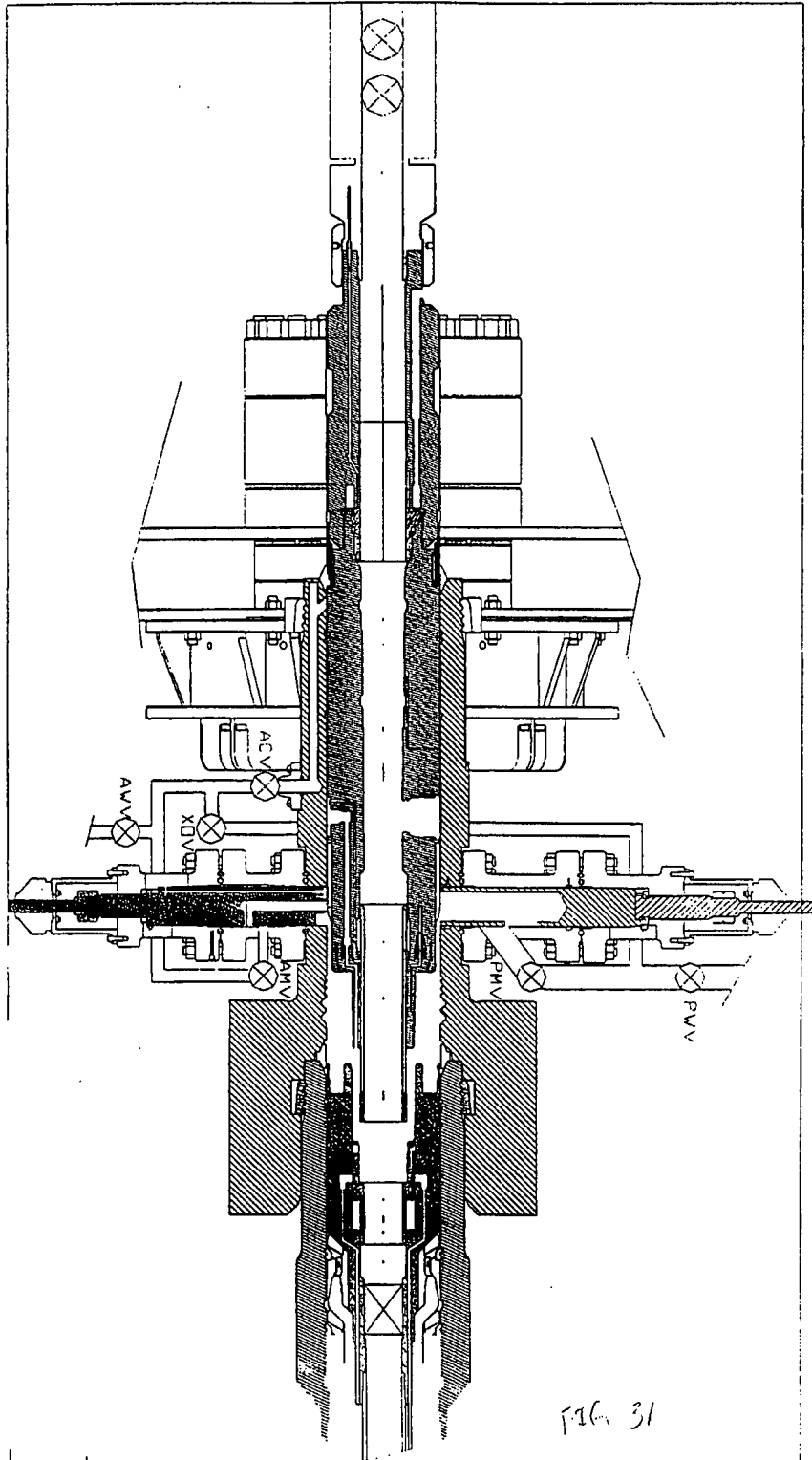
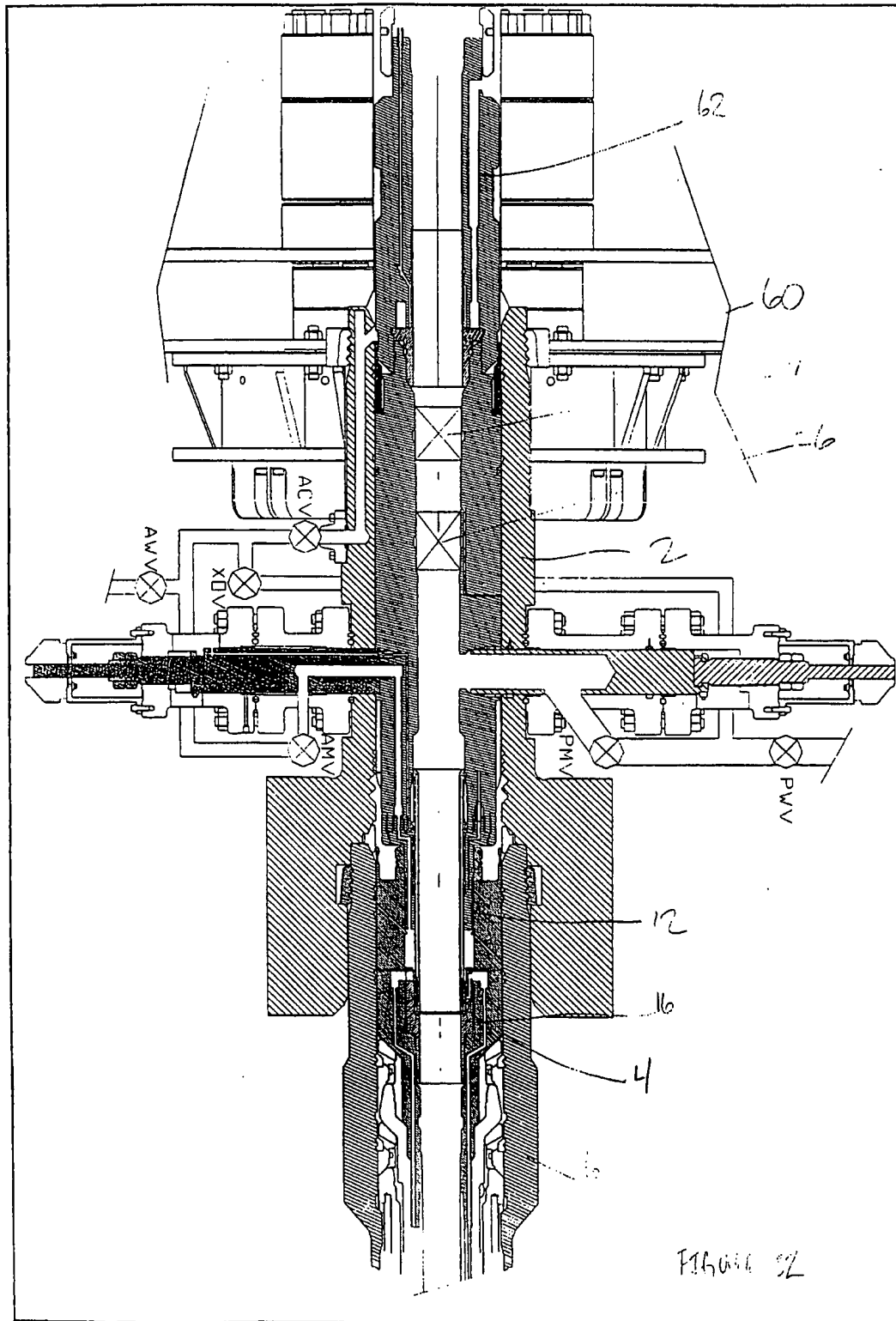
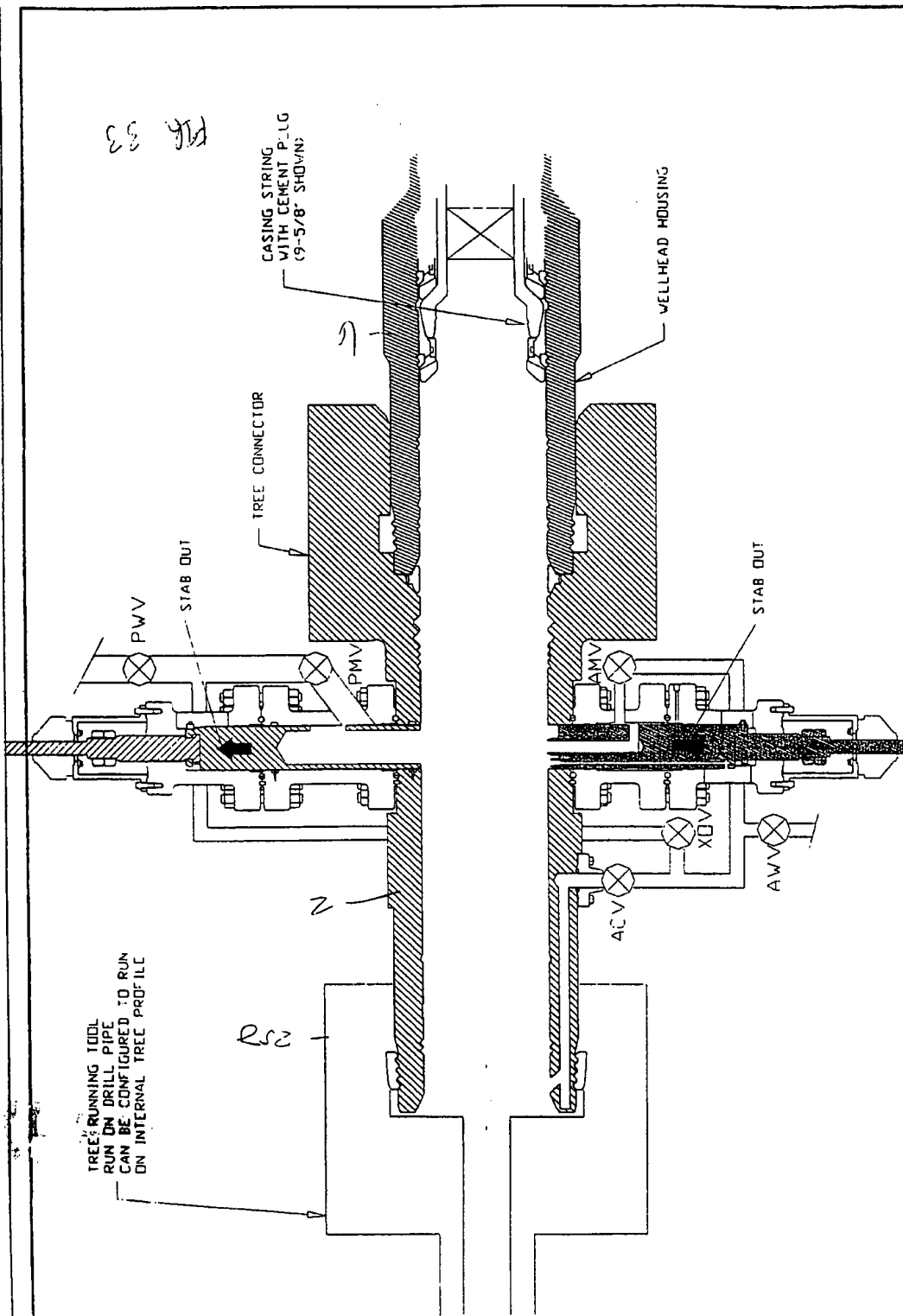


FIG. 31

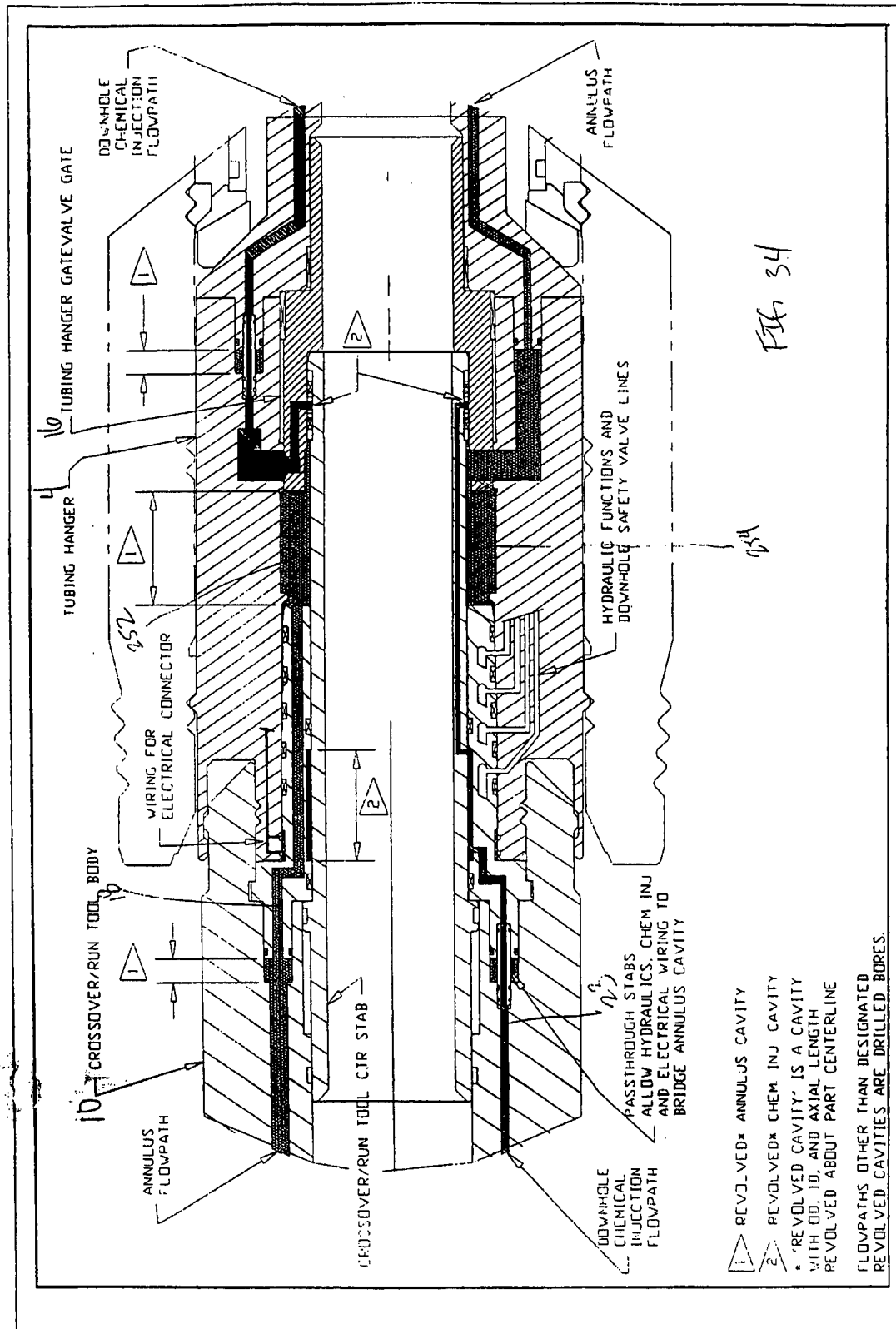
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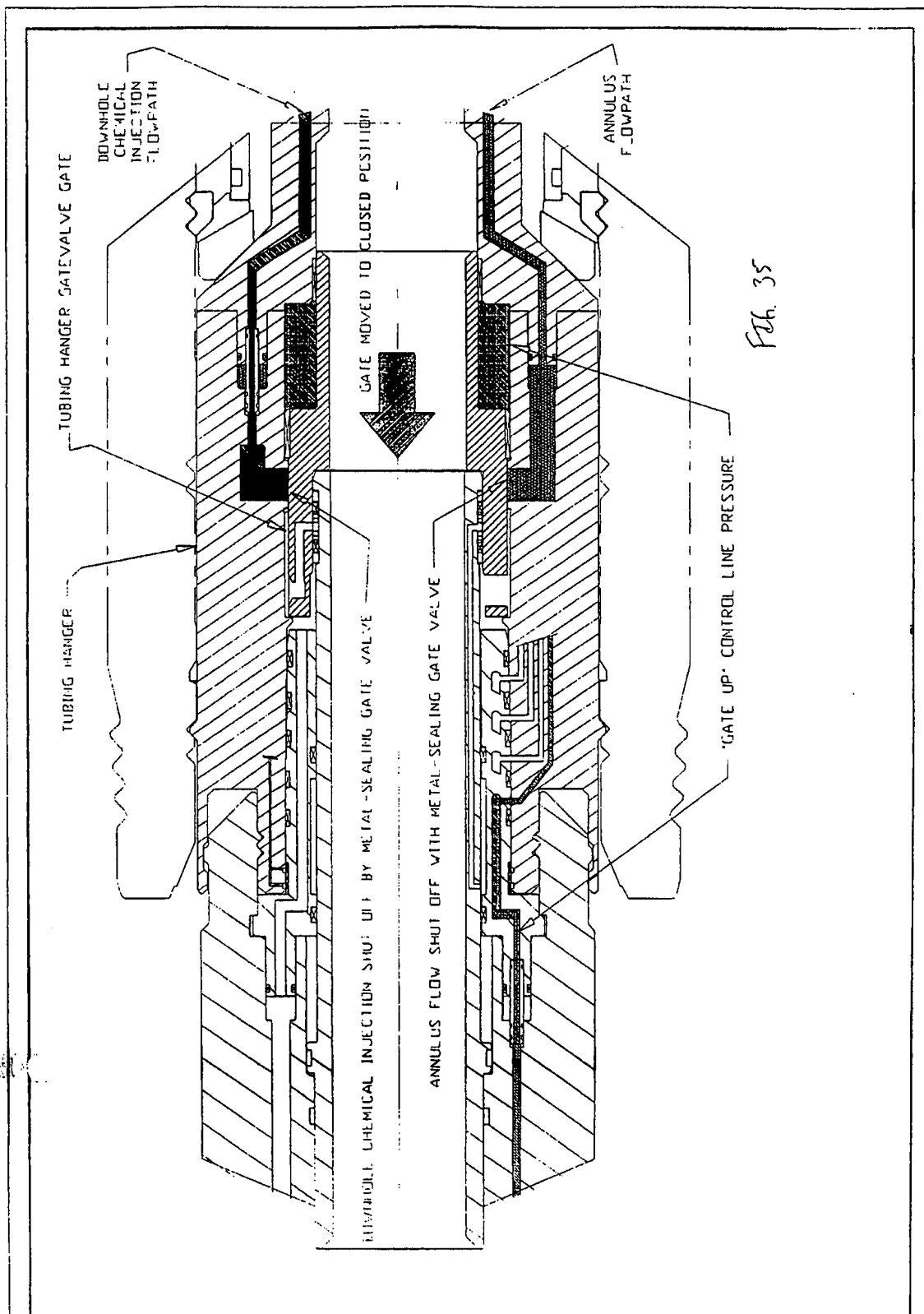
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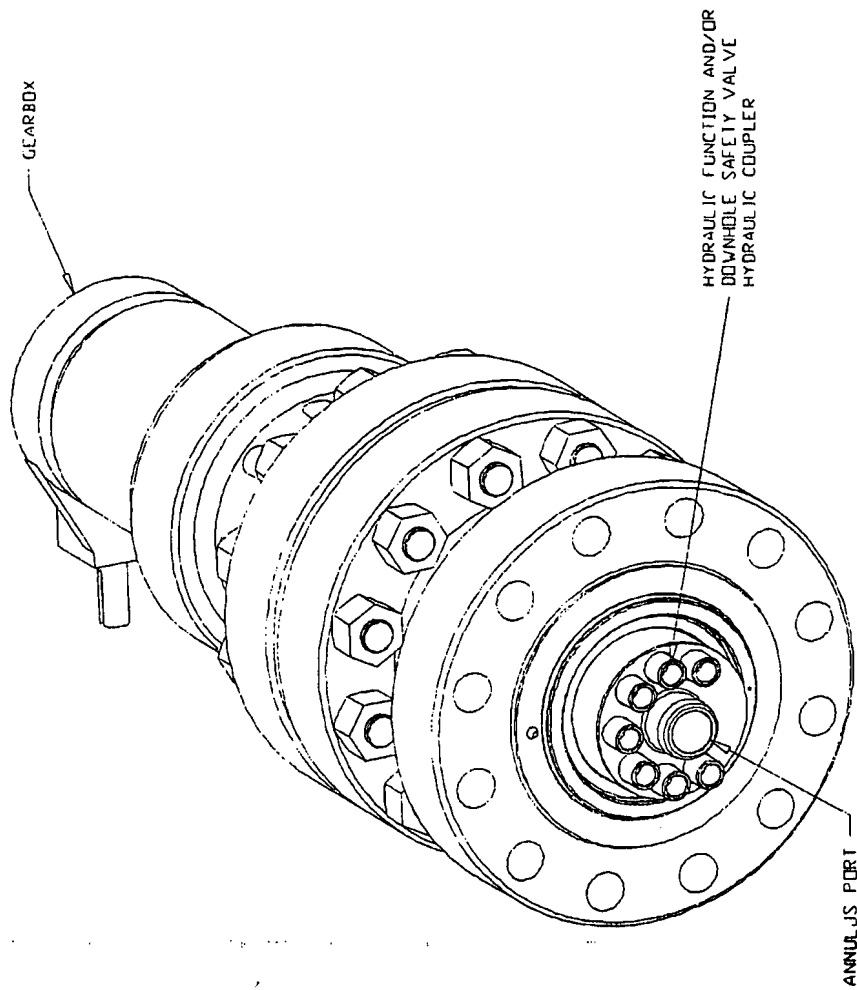
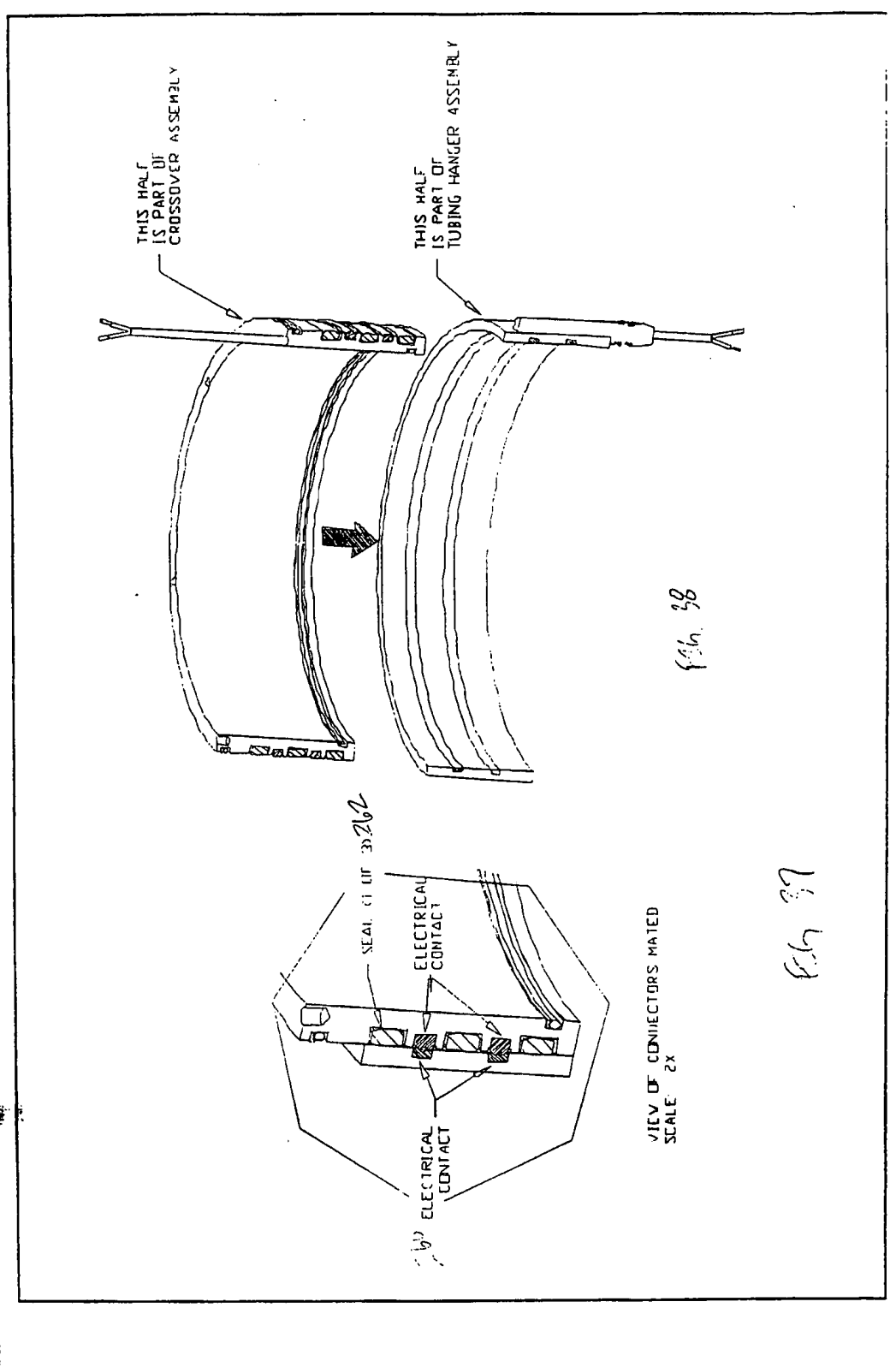


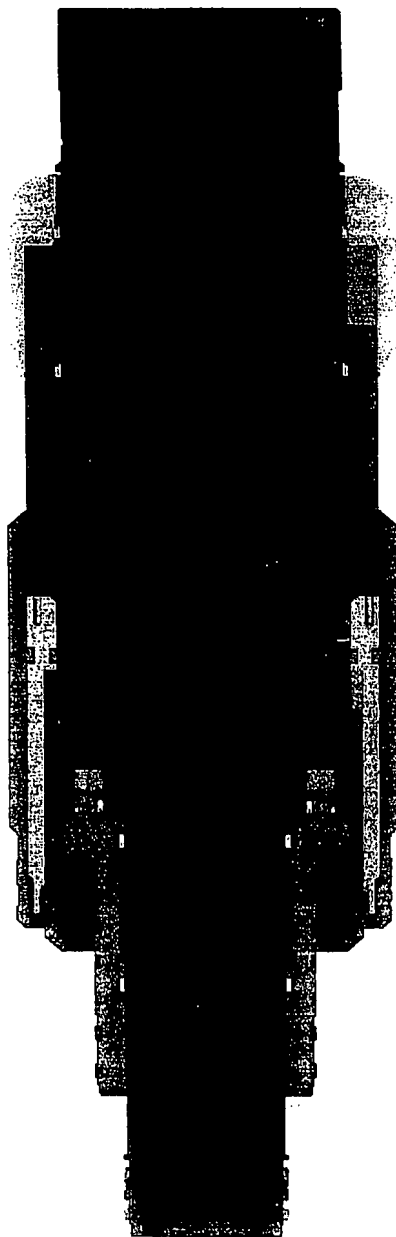
Fig. 36

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CTS Multiple-Use Running Tool (MURT):



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INTERNATIONAL SEARCH REPORT

International application No.

PCT/US01/02938

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : E21B 33/04

US CL : 166/368, 382, 332.1

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 166/368, 382, 332.1, 88.1, 88.4, 319

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WEST

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4,133,378 A (GANO) 09 January 1979, entire document.	1-57
A	US 4,154,298 A (GANO) 15 May 1979, entire document.	1-57
A	US 4,886,121 A (DEMNY et al) 12 December 1989, entire document.	1-57
A	US 5,544,707 A (HOPPER et al) 13 August 1996, entire document.	1-57
A, P	US 6,062,314 A (NOBILEAU) 16 May 2000, entire document.	1-57



Further documents are listed in the continuation of Box C.



See patent family annex.

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E earlier document published on or after the international filing date	*Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
L document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*A* document member of the same patent family
O document referring to an oral disclosure, use, exhibition or other means	
P document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

27 MARCH 2001

Date of mailing of the international search report

27 APR 2001

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